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H. L. Horning, *President* Coker F. Clarkson, *Secretary* C. B. Whittelsey, *Treasurer*

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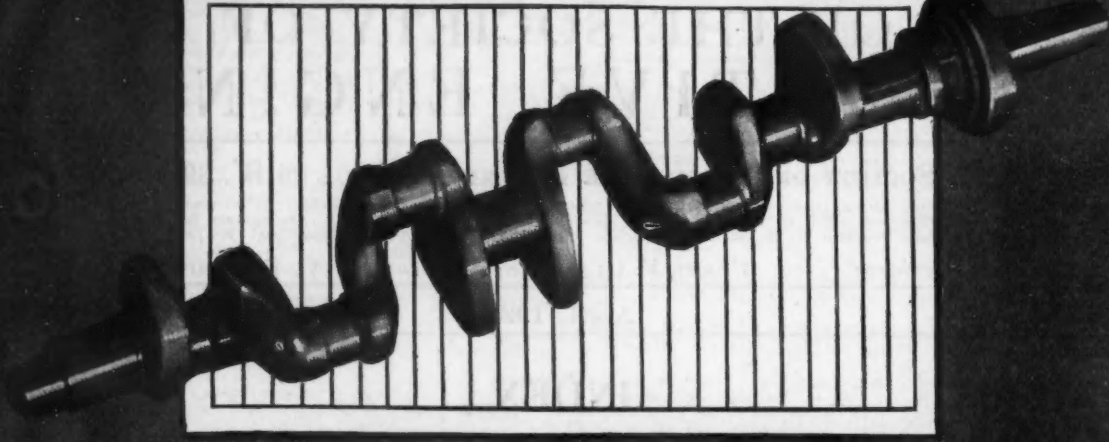


THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XVI April, 1925 No. 4

Chronicle and Comment

Tractor Meeting This Month

ENGINEERS interested in the various phases of the tractor industry will have an opportunity at the National Tractor Meeting this month to contribute and to receive valuable technical information applicable to the solution of outstanding problems.

Chicago has again been chosen as the site of the meeting. The sessions will be held in the Great Northern Hotel on April 29 and 30, the morning and afternoon events of the latter day being under the auspices of the Society of Automotive Engineers, whereas those of the 29th are being arranged by the American Society of Agricultural Engineers with which the Society is cooperating.

Further particulars are presented on p. 387 of this issue of THE JOURNAL. Additional information will be published in the *Meetings Bulletin* that will be mailed to the members about the middle of April.

March Issue of S.A.E. Data Sheets

THE S.A.E. Standards and Recommended Practices approved by the voting members of the Society on Feb. 28 will be issued in data sheet form during the present month. Many of these standards, as for instance the standard for motor-truck storage-batteries, represent potential possibilities for tremendous economic savings. Without general adoption by industry, however, these savings will not be realized. Although the actual adoption of the battery standard by any one truck manufacturer may mean considerable expense, the resulting gain which is cumulative, may not be immediately appreciated. It is hoped, however, that engineers and purchasing agents, as well as executives, will appreciate the ultimate goal and authorize the adoption of standard-size batteries, if these are not already being used, when changes in design or production make this possible.

Advancement in Aviation

WHAT can the Society do further to foster the steady progress of aviation in this Country? Engineering discussions have been held frequently at meetings of the Sections and at the gatherings of National scope. It has been the intention to bring out the best of material at these meetings and to encourage the expression and dissemination of ideas that are based upon sound engineering principles. Furthermore, the Society members have been active in supporting various projects, the formulation of the Aeronautical Safety Code, for example, that are of vital import to aviation activity.

A number of prominent representatives of the industry met in New York City on March 26 and considered the possible ways in which the Society could be more effective in its aviation work. Several valuable suggestions were contributed. A committee is to be chosen to confer with the Council with regard to the details involved.

The following were among those present at the meeting: Charles H. Colvin, H. M. Crane, F. G. Ericson, W. L. Gilmore, C. W. Hall, C. L. Lawrance, A. T. Loening, G. J. Mead, G. B. Post, C. M. Vought, E. P. Warner and P. G. Zimmermann.

Promotion of Standards

IN a paper presented at a session of the executive committee of the American Engineering Standards Committee, by Ray M. Hudson, chief of the division of simplified practice of the Department of Commerce, the demand for wider adoption and use of standards was emphasized. In Mr. Hudson's opinion standardizing bodies should include in their activities a "standards promotion service." Obviously, the success of a standard is determined by the extent of its use. Accordingly, frequent investigation should be made of the use of standards or recommended practices. Mr. Hudson said that, so long as a standard is applied in only relatively few of the cases in which its application is possible, there is a proportionate economic waste. The waste resulting from the non-adoption, or relatively slow adoption of available standards, can be overcome only by specific effort to accelerate their adoption. In the interest of minimizing waste it is essential that the advantages inherent in a standard be thoroughly and persistently demonstrated. There is little use of continuing to pile up standards merely in the hope that they will be used extensively.

It is part of the program of the Division of Simplified Practice to further the making of periodic resurveys to

determine the extent of actual reduction to practice of recommendations formulated. Undoubtedly, this is an essential feature of standardization work. The Society is following this practice in the case of its own standards and has made recently a thorough investigation of the extent of use of its spark-plug and head-lamp glass standards. Other similar surveys are in hand.

1925 Roster

THE 1925 Roster is being mailed to the 2000 members who ordered copies. As heretofore, the main divisions of this printed list of the membership of the Society are the alphabetical register of members; the list of companies, with names of members associated therewith; and the register of members arranged according to their residence. In addition, members connected with the Army, the Navy, United States Government bureaus and schools and universities are listed separately. The book contains also uptodate lists of the officers, committeemen and representatives of the Society and of officers of the Sections nominated for service during the coming season. Among the miscellaneous bits of information given is a tabulation of the number of members residing in the various States of this Country. Nearly 4500 members are located in 11 States. In numerical order these are

New York	934
Michigan	915
Ohio	610
Illinois	474
Pennsylvania	358
Indiana	251
New Jersey	227
California	207
Massachusetts	201
Wisconsin	158
Connecticut	117
Total for 11 States	4,452

The other members residing in this Country are located in 32 other States. In addition, 193 Affiliate Member Representatives and 183 Enrolled Students resident in this Country and abroad are on the rolls of the Society. Two hundred and forty-seven members have their places of business outside of this Country. The total number on the rolls of the Society as of March 1, 1925, which is the date for which all of the figures are given above, is 5445.

Prospects in the Automotive Industry

THE farms of our United States produced $12,404,000,000 from the ground during the year 1924, reports the Department of Agriculture. This is an increase of $56,000,000 over 1923. The purchasing power of the agricultural districts, and all lines of business and effort, will be greatly augmented by the reallocation of a large portion of this immense amount of money.

The automotive industry should benefit, even more than other lines, for with prosperity in the ascendency the inclination to keep the old car on the job during a number of lean years, even though the expense of heavy repairs make it very uneconomical, is eliminated; and, when better days arrive, the "come-on" for the purchase of a new model, with its improvements and economies, is keenly felt and promoted by the whole family.

The year 1925 promises to be a good year in automotive circles and manufacturers are preparing to meet the demand. Capacity is ample though experience justifies conservatism and production will be held within the bounds of actual business in sight. Today the industry is able to appraise the demand much more closely than in years past. This is a healthful condition and should result beneficially to all parties concerned.

The next half-dozen years promise to be no less interesting in the development and refinement of the passenger car, truck, tractor, motorbus and airplane than those just past. One change or improvement brings about others, just as the balloon tire may result in the redesign of the entire car, making it lighter because it is not subjected to the excessive shocks usually met when the old style small high-pressure tires are used.

The use of higher-grade materials, with a better distribution of them and a better understanding of metallurgical science, may bring about further economies in weights. If the redesigning of the car falls into progressive hands, new alloys may be used in many important members, adding strength and reducing weight. Unsprung weight will receive special attention with a view to a reduction in the weight of those members below the springs that were designed with a large factor of safety because of the stresses to which they were subjected. This will result in a lessening of the punishment of the tires and the road. The automobile is past its age of minority. Just reaching maturity, it is in the full bloom of its youth.

Report on Gaging Supplements Standard

THE Sectional Committee on the Standardization and Unification of Screw-Threads, which is sponsored by the American Society of Mechanical Engineers and this Society, and the National Screw-Thread Commission, on which the two societies are represented, have formulated a report on gages and gaging as a supplement to the present American Standard for Screw-Threads that was approved by the American Engineering Standards Committee in May, 1924. The purpose of the report is "to establish the fundamentals of gaging and to point out practices now used successfully." The report describes working, inspection and master or setting and reference gages and their uses, gaging practices and specifications for gages. The gaging of screw-threads is treated at some length with regard to classes of product to be gaged, the several methods of gaging threads with thread micrometers; snap, cone-pointed, ring and plug and indicating gages and screw-thread comparators and their use and care. Under the title Specification for Gages much valuable information is given regarding the classification of gages according to the desired accuracy of the work, placing and amount of tolerances allowed on the gages and their application. Many valuable numerical data are given in several tables which include recommended uses for classes *X*, *Y* and *Z* gages and tolerances for the "go" and "no-go" gages for work ranging from 80 to 4 threads per inch. The limiting dimensions for the "go" and "no-go" setting-plug and ring gages for screws and nuts of the National Coarse and National Fine Thread Series are tabulated for all four classes of screw-thread fits, namely, Loose Fit (Class 1), Free Fit (Class 2), Medium Fit (Class 3) and Close Fit (Class 4).

The report is very valuable for use in all practical screw-thread work, especially where a greater degree of accuracy is desired for interchangeability of product in large quantities or close assembling fits. Although the report is not yet in printed form, it probably will be issued in the near future by the American Society of Mechanical Engineers and will be obtainable at a nominal price. Inquiries regarding it should be addressed to the Society headquarters, as such inquiries will be used as a guide to the number of copies to be printed.

MEETINGS OF THE SOCIETY

TRACTOR MEN TO THE FRONT!

Annual Tractor Meeting in Chicago To Cover a Wide Range of Topics

Time: 10 a. m., April 30. Place: Great Northern Hotel, Chicago. Event: Opening session of the National Tractor Meeting of the Society of Automotive Engineers. On April 29 the American Society of Agricultural Engineers, with which the Society is cooperating, will hold its sessions. On the evening of the 29th members of both Societies will gather to view a series of interesting motion pictures showing tractor developments and applications. The program for each of the sessions will include engineering papers of real value to those who attend. Opportunity will be afforded for extensive discussion.

Sessions on April 30

Two technical sessions will be held, one in the morning starting at 10 o'clock and the other in the afternoon starting at 1.30. An informal luncheon at which several tractor pioneers will speak will occupy the interval between the sessions. The sessions and the luncheon will take place at the Great Northern Hotel. All members of either Society are welcome and may bring guests.

President Horning Among Speakers

President Horning will honor the meeting by his presence. He will speak on Tractor Engine Research and will refer especially in his address to problems relating to combustion, lubrication, clean air and dilution. A valuable and instructive paper ably presented is to be expected.

George D. Babcock will discuss Recent Developments in Production Methods and Equipment. In view of his wide experience and his position as manufacturing executive of the Holt Mfg. Co., Mr. Babcock is eminently qualified to contribute worthy material relating to the subject above mentioned.

Max Sklovsky of the John Deere Co. will also speak on Developments in Production Methods and Equipment.

L. B. Sperry, International Harvester Co., will contribute a paper of unusual interest on the Influence of Tractor Engine Development on Automobile, Truck and Motorbus Engine Design.

E. W. Stewart, of the William D. Gibson Spring Co., who has done a great amount of very creditable engineering work on springs, will present a paper on the Calculation and Design of Coil Springs. This paper will include a wealth of practical information.

The tractor activities of the Ford Motor Co. have always been of great interest. Details relating to various phases of this work will be presented.

Inspection Trips

Visits will be made after the sessions to the Hinsdale Farm and the Insul Farm, both near Chicago, where power-operated machinery in regular and experimental use will be in action.

Notification

Further information concerning the Tractor Meeting will be made available to the members in a *Meetings Bulletin* to be issued soon. Those who expect to attend any or all of the sessions are requested to notify at once O. B. Zimmerman, International Harvester Co., 606 South Michigan Avenue, Chicago, who is chairman of the committee in charge of the meeting.

SUMMER MEETING EVENTS PLANNED

Meetings Committee Announces Tentative Program for Technical Sessions

Transmissions, brakes, gasoline-electric buses and railcars, fuel utilization, lubrication, highway safety and research dealing with riding-qualities and noise have been chosen by the Meetings Committee as topics of timely interest to the members and thus appropriate for consideration at the Summer Meeting at White Sulphur Springs, W. Va., June 16 to 19. A number of excellent papers covering the above topics have already been secured, but the Committee would be pleased to hear from members who have material that they would care to present at any of the meetings of the Society.

In addition to the technical sessions a well planned program of sports events will be open to all at the Summer Meeting. Various entertainment features will also be presented. The general schedule of the sessions as tentatively arranged is given on p. 388. Further details will appear in the *Meetings Bulletins*.

View from the Porch of the Casino

This Photograph Was Taken Looking West over the Nine-Hole Golf Course at White Sulphur Springs, W. Va.

NATIONAL MEETINGS CALENDAR

TRACTOR MEETING
Chicago—April 29 and 30

AUTOMOTIVE SERVICE CONVENTION AND MAINTENANCE EQUIPMENT SHOW
Detroit—May 20-23

SUMMER MEETING
White Sulphur Springs, W. Va.—June 16-19

MOTORBOAT MEETING

PRODUCTION MEETING AND EXHIBITION
Cleveland—Sept. 15 and 16

AUTOMOTIVE TRANSPORTATION MEETING
Philadelphia—September

AERONAUTIC MEETING

SERVICE ENGINEERING MEETING
November

ANNUAL DINNER
New York City—January 14, 1926

ANNUAL MEETING
Detroit—January, 1926

TENTATIVE SCHEDULE OF SESSIONS

Tuesday, June 16

Morning—Registration and assignment to rooms
Afternoon—Session on Transmissions
Evening—Semi-Annual Business Meeting

Wednesday, June 17

Morning—Session on Fuel Utilization and Lubrication
Afternoon—Session on Highway Safety
Evening—Session on Gasoline-Electric Buses and Rail-Cars

Thursday, June 18

Morning—Standards Committee Meeting
Afternoon—Annual Field Day
Evening—Session on Research followed by Grand Ball

Friday, June 19

Morning—Session on Brakes
Afternoon—Athletic events; conclusion of tournaments
Evening—Close of meeting; departure of special trains

STANDARDIZATION OF FRAMES

Expense of Small Variations of Dimensions Stressed at Milwaukee Section

How far can standardization be applied to the design and construction of automobile frames? Are the requirements of other parts of the car so varied that a particular type and size of frame is necessary for every car that is designed, or are the other parts of the car that determine the dimensions of the frame becoming so standardized that producers of cars in the same price class will soon be able to use uniform frames? L. M. Schwab, assistant production manager of the A. O. Smith Corporation, led the discussion of this interesting topic at the monthly meeting of the Milwaukee Section held at the Blatz Hotel on March 4, taking for the subject of his paper The Standardization of Automobile Frames.

Each different size of frame, he said, requires a complete set of dies and a considerable amount of time in making the set-up. The lengths of six frames picked at random varied from 152 to 160 in.; the drop varied from 4½ to 6 in.; the number of cross bars that tie the frame together varied from 3 to 4; the front width ranged from 27½ to 30 in.; the length of the rear spring, from 48 to 54 in., and the cross-section, from 5 to 6 sq. in.

The frames are all just enough different, said Mr. Schwab, so that the same frame cannot be used for two different makes of car. In trucks, however, the dissimilarity is not so great. On one particular car, 375 distinct operations are required to produce the frame, which is handled by 560 men in passing through the various departments.

SAVING IN SET-UP TIME

Although the time will probably never come, in Mr. Schwab's opinion, when a run of 100,000 identical frames can be sold to 10 leading manufacturers, if a plan could be worked out whereby even 10, 15 or 25 per cent of the parts could be standardized or partly standardized, a great saving could be made in the set-up time, in making of special tools and in the special handling that the frames must now receive.

A special press, said to be the last word in press design, that has recently been installed in his plant, was described. Its height is about 30 ft.; its weight is more than 5000 tons; it delivers 4000-ton blows at the rate of 6½ per min. and will form the largest motor truck or motorbus side-rail now being made in this Country in one stroke. Former methods required two or three bites to make the same rail. The average rate of production of the large machine is 6 frames per min., or 3600 frames in a running-time of 10 hr. Three other units operate in conjunction with the large unit:

one, which assembles the spring hangers on the side-rails; a second, which automatically blows the rivets into the parts by compressed air, and the third, a painting unit. The set-up time for these units is from 10 to 15 hr.

Kick-Up and Width of Blank

When asked in what factors standardization would be most beneficial, Mr. Schwab referred to Mr. Taugher, frame engineer of the A. O. Smith Corporation, who specified, first, the kick-up, and, secondly, the width of the blank, which, if standardized, would enable all frames that come under that classification to be run through the first operation. Width of flange, he said, varies needlessly in many cases. Standardizing them would simplify the blanking operation, and a solid die could be used that could be left set-up from run to run. Spring hangers might be standardized as regards the shape of the tail and the number of rivets required to fasten the tail to the side-bar. Some designers use a little lug to hold the spring bolt; others tap the side-bar.

More difficulty, Mr. Taugher believed, would be found in standardizing the cross members, which take their shape, beginning at the front end, largely from the manner of mounting the radiator. Some designers prefer a radiator that is low and sits rather far down; and the cross members must be bent to support it. It may be supported in one of three ways by (*a*) a cross member, (*b*) a bracket projecting from the bar that supports the engine or (*c*) a little bracket put on the radiator itself so that it can be mounted on top of the side-rail. From the manufacturer's standpoint, the last mentioned method is the simplest.

Causes of Variations in Design

In endeavoring to analyze the causes of the variations in design, Mr. Taugher said that he had concluded that they might be due to conflicts of patents and to efforts to avoid infringement. As a result, there is the straight-line or tapering, the conventional bottle-neck and the straight parallel frame.

In W. R. Mertins' opinion, certain points in frame design have already been standardized, such as the straight side-rail, and the width of the springs. The principal one remaining is the cross-section of the frame.

Chairman George W. Smith suggested that, inasmuch as some conditions of design were fixed and others not fixed, compromises are necessary. Individuality of outline is the aim of designers. As the dimensions of the parts vary, the frame, which is a sort of intermediary between the wheels and the body above, are modified to meet the caprices of the individual engineer.

W. S. Nathan believed that as the sizes of wheels and tires and the types of axle construction for cars of different weights become fewer, they will have a determining effect on the frame, especially as regards the rear axle kick-up, so that frame dimensions and sizes may become standardized.

Manufacturers' Standards

A suggestion was made by Joseph B. Armitage that if manufacturers should specify certain dimensions as standard and designers knew that other dimensions would cause additional expense, the standard dimensions would probably be adopted. Natural progress, in his opinion, retards standardization; individuality and the incorporation of new ideas cause additional expense until such changes are forced upon the rest of the industry. Mr. Nathan disagreed with the last statement and remarked that those who had watched the progress of standardization carefully believed that individuality has been in no way sacrificed. Any improvement is quickly noticed and is adopted as standard by the industry.

In reply to a question as to how far his company had gone toward putting standard frames on the market, Mr. Schwab stated that although little had been done in that direction the company did, however, make suggestions regarding economy of manufacturing when new designs were offered. The set-up time, he said, on a press that cost $150,000 is from $25 to $50 per hr.

TRANSMISSIONS DEMONSTRATED

Various Types of Recent Speed-Change Mechanisms Shown to Indiana Section

Several cars in which recently-developed power-transmission mechanisms were embodied were demonstrated on the street in Indianapolis during the afternoon of March 12, preceding the meeting of the Indiana Section at the Hotel Severin on that evening.

The regular monthly meeting was presided over by F. F. Chandler, chief engineer of the Ross Gear & Tool Co., and was devoted to descriptions and discussions of automatic, hydraulic, friction and other types of transmission mechanisms and gear-shifts, the speakers showing models of their devices or illustrating their talks with lantern slides.

Many slides of the Weiss transmission were shown by E. B. Sturges, who described its construction and operation from the pictures.

S. O. White, chief engineer of the Warner Gear Co., said that the Patent Office is full of patents covering automatic and mechanical gear-shifting devices, which fall into two general classes, (*a*) those that operate on the down stroke of the clutch pedal, the gears being positively neutralized and re-engaged by the power of the operator's leg, the cycle of operation being complete when the pedal reaches the floor; and (*b*) those in which the down stroke of the pedal neutralizes and the gear selected is pulled into mesh on the back stroke of the pedal, either by the clutch spring or by an auxiliary spring. In either case a long pedal-travel is necessary and successful operation requires a very free-acting clutch, without drag. Increasing travel through mountainous districts by motorists makes it most desirable, he said, to have a transmission that can be shifted into second speed from high when coasting down hill. The constant-mesh transmission was the most natural suggestion for making the shift easier and surer, and a few devices have been evolved, he said, that are thoroughly practical and satisfactory, although none of them can be made as cheaply as the conventional sliding-gear type of transmission.

Constant-Mesh Hydraulic Transmission

Granting that the mechanical gear-shift clears up the floorboard by dispensing with the hand shift-lever, and that the constant-mesh transmission is desirable, Mr. White said that he and his associates believed they had a combination of the desirable features of the two systems in a new modified form of the hydraulic transmission developed in Germany, where it has been in use for the last 3 years in tractors, locomotives, trucks and fire apparatus, and brought to this Country by the Hydraulic Transmission Co. The Warner Company has reduced its proportions to adapt it for American passenger-car purposes.

In describing the transmission Mr. White said:

> Strictly speaking, it is a constant-mesh geared transmission having an individual clutch for each speed, the clutch being applied by oil under pressure. The main engine-clutch is dispensed with, together with the throw-out yoke, thrust bearings, shafts and pedal mechanism. In the transmission proper there are no shift rails, forks, poppets, interlock mechanism or control pedestal. Taken as a whole, this transmission is much the simplest and most practical solution of the hydraulic problem we have seen. . . . The addition of a fourth speed would mean simply the adding of another set of clutches and one more position on the control segment but no added difficulty or complication of operation for the driver.

Describing the operation and construction, he said that a small control lever and segment is located on the steering column such as would be provided for a mechanical gear-shift, with a simple and direct linkage carrying the motion back to a distributer valve at the rear of the transmission that directs the flow of oil under pressure to the desired clutch. Driving is done by moving the control lever from

notch to notch of the segment as the car gathers headway, there being no clutch to release and no coordination of movement between the left foot and the right hand, except that a small pedal or button like an accelerator should be provided to cut-off all pressure in case of emergency.

The main drive-gear is driven directly from the engine flywheel and drives a countershaft having four gears, as is customary in three-speed transmission construction. The idler gear is also in the constant-mesh train, being fixed to its shaft, which drives a pair of pump gears in a housing at the rear of the transmission case. A splined main driving-shaft carries four individual clutches that are operated by oil under pressure that is carried through leads in the main shaft. The front clutch operates the high-speed gear, the next one the second speed and the last one the reverse gear. To start the car, the control lever is moved to first speed position, permitting oil under pressure to force the first-speed clutch into engagement. When passing into second speed, the pressure is cut-off from the first-speed channel and directed into the second-speed channel, and so on. The oil used for pressure is ordinary transmission oil and is pumped from the base of the transmission case after passing through a fine-mesh screen.

Friction Drive Again Advocated

Use of the friction transmission, especially for small light cars, was advocated by C. A. Trask, efficiency engineer of the Rockwood Mfg. Co., who recalled that the 1913 Glidden Tour through Minnesota, North Dakota and Wyoming was won by a team of three friction-drive cars that finished with perfect scores. He also pointed out that thousands of tractors with friction transmissions are pulling gang plows and heavy loads and that hundreds of industrial locomotives with the same device are in successful operation. He showed a number of slides of a chainless spur-and-disc friction transmission as applied to a modern car and said that the chain was one of the troublesome features of the friction-drive cars of 10 or 15 years ago. The simplicity, silence, infinite range of speed changes and efficiency were mentioned as points of special appeal.

Cam-Operated Gear-Shifts

A. C. Nicholl, Jr., of Waukesha, Wis., illustrated with slides and described his cam-operated mechanical gear-shift, which he said could be applied to any present transmission except the planetary. One of these gear-shifts was fitted to a car that had been demonstrated in the city street in the afternoon and had been in service for 4 years. The mechanism operates through the action of sliding cams and a spring that moves the gears, easing them into mesh instead of forcing them in. There are only three major parts. The shift acts on the downward movement of the clutch pedal and is positive.

The Cutler-Hammer gear-shift used on the Apperson cars for the last 2 years is very similar to the Nicholl shift, said Mr. Buxton, of the Apperson Company, the operation being the same except that in the Cutler-Hammer the neutral position is between reverse and first speed while in the Nicholl it is between first and second speeds.

Pre-Selective Automatic Shift

A model of a fully automatic and pre-selective shift was shown by Mr. Alspaugh. The quadrant is moved from neutral, he said, and placed in automatic position when the driver has selected all the shifts required. At the first movement of the foot, it goes into low, at the second into second, and at the third into high. Thereafter, with each successive movement of the foot the shift works automatically between second and high. The device can be thrown into neutral automatically, pick up its operation out of second and continue working between second and high out of automatic. Then it can be changed into selective, pre-selective or semi-automatic, as the speaker called it. The actual working parts weigh between 3 and 4 lb. With one setting of the quadrant the driver gets any operation he wants, with continuous shifting as long as the car does not have to be reversed, when a hand operation is required.

I. L. Campbell said that in his transmission, which is used on the Chandler car, the method of clutching the gears is by a key that rolls into position automatically and engages the gear. Engagement is positive in both directions, he said, whether the key is actuated by a wabble stick or a shifting device. This transmission is used on as small a vehicle as a two-wheel railroad inspection car and on as large a one as a 60-passenger motor rail-car.

Points Brought Out in the Discussion

Considerable discussion that lasted until well past the regular adjournment hour followed the delivery of the addresses. Replying to questions, Mr. Sturges said that when his device is in neutral the driven end is locked against motion and whether going up or down hill it is not necessary to depend upon the emergency brake, and that a change of speed can be made at any time without disengaging and while running the engine at maximum torque. Any reduction ratio, from zero to direct drive, is obtainable without disengaging, he said. When the motor is traveling at high speed no motion occurs but solid shift and in neutral position the bearings are stationary, so running at exceptionally high engine-speed is not objectionable.

Mr. Nicholl, replying to questions, said that, aside from the three major parts in his device, the hook-up is a simple matter of leverage. It can be applied to any car with constant-mesh or conventional sliding-gear transmission, whether of the unit-powerplant, mid-shift or rear-axle type layout.

Mr. White raised the point whether a driver could change his mind and select another gear speed when the pedal is all the way down to the floor, and Mr. Nicholl explained that a neutral point is provided at which the clutch can be held back and any desired shift made. Another member inquired whether a driver who is inexperienced in the use of any of these gear-shifts has any trouble shifting gears when he intends only to declutch a little. In response, Mr. Nicholl said that when the selector is left in high and the clutch is released and then let in again, the shift remains in third and does not go into neutral. The same is true of all the other speeds.

O. C. Berry asked Mr. Alspaugh whether, with his device, it was possible, after going into neutral, to go from high into second or from second into high, as desired. Mr. Alspaugh replied that it was possible but that it was not necessary when shifting from high down to second to go into neutral, and that the clutch could be released without shifting any gears. If the driver becomes excited and pushes automatically on the pedal, it will shift from high into second and then from second into high again.

POWER BRAKES ON HEAVY VEHICLES

Buffalo Section Told That Motorbuses, Motor Trucks and Heavy Cars Need Them

Automotive airbrakes were described and discussed at the meeting of the Buffalo Section held on March 17, the paper presented being by H. D. Hukill, in charge of the automotive division of the Westinghouse Airbrake Co., Wilmerding, Pa. About 100 members and guests attended. The full text of the paper was published in the March, 1925, issue of The Journal.[1]

Much interest in this subject was manifest during the discussion, and Mr. Hukill answered numerous questions. In reply to J. W. White's statement of his belief that the greatest retardation effect is obtained when approximately a 50-per cent slippage of the wheel occurs, Mr. Hukill asserted that, assuming the brakes to be equalized, there can be no point of 50-per cent wheel-slippage and said that the tires either are rolling or they are locked and sliding. If they lock, the airbrakes can be eased off a trifle until the maximum retardation effect is produced.

[1] See The Journal, March, 1925, p. 283.

In connection with W. R. Gordon's queries, Mr. Hukill brought out that small quantities of oil and water have no noticeably bad effect under ordinary service conditions; they are on the surface of the brakeshoe and are quickly burned off by the heat evolved during brake applications. Under maximum brake application, the pressure on the brakeshoes is from 150 to 200 lb. per sq. in. As to the time interval elapsing between the application of the air and the actual "taking hold" of the brake-lining, this has been minimized by the addition of an application release or relay valve. In case of a leaking connection, the brake valve will maintain the line pressure against such leaks up to the capacity of the valve. It is possible, also, to install double check valves in the brake lines so that the complete rupture of a line will seal that line, leaving all other brake lines fully effective, without leaking. Regarding oil gumming, the compressor is never operated continuously at maximum speed in service installations, and usually is mounted so as to receive a cooling draft from the fan; since oil gumming in a compressor is caused by carbonization of the oil at high temperature, this is obviated by providing an ample margin of safety against overheating. Speaking of the metal-to-metal brake-contacts, Mr. Hukill stated that a 90-point carbon-steel brakeshoe, or a special 70-point carbon-steel with a small percentage of nickel and chromium, is being used at present; and that the drum-liners are made of 10 to 20-point carbon, mild steel. The brakeshoes and liners take a polish without scoring and are noiseless in service.

L. H. Pomeroy pointed out that the stopping force obtained from an internal brake not only depends upon the angle embraced by the brake-lining but also upon the relation of the brake-lining to the fulcrum pin of the brakeshoe. He said that if the end of the brake-lining is disposed with regard to the fulcrum so that the included angle between two lines, one drawn from the end of the brake-lining to the fulcrum and one drawn from the end of the brake-lining to the center of the wheel, be such that its tangent is less than the coefficient of friction, the brakeshoe positively will lock. Mr. Hukill then cited an instance of this that actually occurred in service. With ordinary mechanical fabric-lined brakes, in a case where a 21-in. brakeshoe was mounted on a brake spider originally intended for an 18-in. brakeshoe, the brake was self-locking when the coefficient of friction of the brake-lining was 0.5 or more. Occasionally the friction did have this value and the slightest pedal operation would lock the system so that it would become necessary to throw the mechanism of the car into reverse gear to release the brakes.

Mr. Hukill said further that the ventilated brake-drum is just coming into use, but that no trouble due to sand or dirt is anticipated. The idea of using ventilation ducts in the drum is to assist in cooling. No trouble, he stated, has been experienced due to shearing of drum-liner rivets.

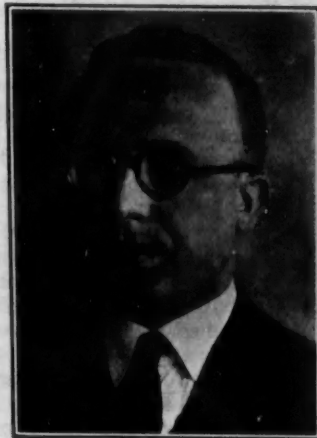
HOFFMAN CORRECTS STATEMENTS

Prof. A. H. Hoffman has called attention to two loose statements in THE JOURNAL for February in the report of the Air-Cleaner Session at the Annual Meeting that are open to wrong construction. One is that "in his opinion, manufacturers were making a mistake in not providing means for heating the air to facilitate starting in cold weather." What he meant was "to facilitate warming-up," the idea he intended to convey in his address on air-cleaner tests, being that it was not advisable to design an air-cleaner so that its application to a given machine would require removal of a heating device without supplying a satisfactory substitute.

In the report of Mr. Summers' address it was stated that "a centrifugal air-cleaner patterned after development by Professor Hoffman was demonstrated." It was not the cleaner but the equipment for testing cleaners at the General Motors Research Laboratory that was patterned after work done by Professor Hoffman, who had nothing to do with development of the A. C. air-cleaner, which was designed by H. G. Kamrath.

MOVIE TRIP THROUGH A BODY PLANT

Pennsylvania Section Sees All Steps in Building of Steel Vehicle Bodies



WALTER A. GRAF

Four reels of motion pictures interested and instructed over 50 Section members and their guests at the meeting of the Pennsylvania Section held in Philadelphia on March 10. The films, which covered all the steps in the process of building steel vehicle-bodies at the plant of the Edward G. Budd Mfg. Co., supplemented the paper presented by Walter A. Graf, assistant engineer of that organization. All of the stages from the preliminary work in building the model of a new body in the experimental department to the pulling away of one of the three freight trains that leave the plant each day with completed bodies were covered.

The operations shown included the making and testing of the dies for the production of body parts; pressing the various units from sheet steel; the use of the oxy-acetylene and the electric welding processes in the fabrication of the various units entering into the body construction; the assembling of the units comprising a body on special jigs; the delivery of the completed bodies after oiling to prevent rusting in transit to the loading platform and the storing of the bodies in the cars. The most interesting of the operations were the assembling of the various units entering into a complete body on a special jig, this operation requiring some 10 to 15 min. per car and the delivery of the completed bodies via a chute extending from the fourth floor of the plant to the shipping platform.

Mr. Graf's paper, which was entitled Building of Vehicle Bodies, was in the main an abstract of the paper[1] presented by Edward G. Budd and J. Ledwinka at the 1925 Annual Meeting of the Society in Detroit. After tracing the development of transportation from its origin to the construction of the self-propelled vehicle, the various demands made upon skilled carriage makers for a proper body for the new vehicle and the way in which they were met were outlined. In this connection the use of wood panels and structural members was commented on and mention was made of the substitution of sheet metal put on in a number of small pieces for the earlier wood panels. Following this came the forming of sheet metal into shapes and the use of structural steel, the result being the steel body built by the Budd Company.

After outlining the characteristics of minimum weight, maximum strength, resistance to vibration, a smooth outer surface, a minimum wall thickness to give the maximum inside seating space and lower cost that the present-day automobile body must possess, Mr. Graf showed how all of these are met by the all-steel body and described in some detail the construction and connection of the different parts, showing how the use of steel construction does away with the waste formerly experienced when wood was employed.

In answering questions that came out in the discussion following the presentation of the paper, Mr. Graf stated that repairs to a steel body after a collision could be rapidly made since if the panels were merely dented they could be straightened out in the usual way; while if they were broken it was possible to remove a complete unit with ease by the oxy-acetylene cutting process and replace it with a similar unit. The average thickness of the side panels, he said, was 0.04 in.

Answering a question regarding the method of attaching the roof to the body Mr. Graf stated that a wooden frame-

[1] See THE JOURNAL, February, 1925, p. 219.

work served as the foundation for the roof which was a separate unit and built on a bench. At the proper time in the assembling process the roof was placed on the body and fastened in place by bolts that projected through the top member of the body. At the conclusion of the meeting an opportunity was given those present to inspect actual samples of the various units described by Mr. Graf in his paper.

Nominations for Section Officers

The meeting was preceded by the usual dinner and at its conclusion a short business session was held. The Nominating Committee reported the following nominees for the Section Officers for the next administrative year of the Section which will commence at the conclusion of the meeting to be held on May 12:

Chairman—Charles O. Guernsey
Vice-Chairman—R. W. A. Brewer
Secretary—Adolph Gelpke
Treasurer—Ellis W. Templin

Richard R. Wittingham was nominated to represent the Section on the Nominating Committee to choose officers for the Society for the 1926 administrative year and G. Walker Gilmer, Jr., was named as alternate. The election of the Section officers and the member and alternate of the National Nominating Committee will take place at the May meeting of the Section.

Future Meetings

The next meeting of the Section will be held on April 14 at which John D. Gill, of the Atlantic Refining Co., will present a paper dealing with the methods of refining the products used in the automotive industry from crude oil. It is hoped that an inspection trip to the plant of the Atlantic Refining Co. can be arranged for the afternoon, with the meeting to follow in the evening. A trip to the Naval Air Station at Lakehurst, N. J., is being considered for the meeting of May 12.

Further information regarding the April and May meetings of the Section can be secured from Charles O. Guernsey, secretary of the Section, who can be addressed at the J. G. Brill Co., Philadelphia.

IMPRESSIONS THAT ARE AN INSULT

Horning Gives Cleveland Section Some Thoughts on Riding-Qualities To Mull Over

With characteristic gravity that only added to the humor of his remarks, Harry L. Horning, president of the Society, gave a talk on riding-qualities and the work of the Research Department at the March 16 meeting of the Cleveland Section. He made some critical comments to cause his hearers to think over past experiences and get them to give the Research Department the benefit of their cogitations. A vast amount of information is available of which we have knowledge but which never has broken through to the stage of definite expression, he said.

The desire of the Research Department is not to invade the province of the engineer in his endeavor to express ideals, but rather to develop general principles that it will be of value to keep in mind at all times during the period of designing. Its most significant function, he said, is to assemble the laws of Nature as known to science and digest them into a form that will aid in applying them to the daily problems of the automotive engineer.

Agreeable riding sensations are a matter of the mental reaction of the individual to nerve sensations and, notwithstanding the sensitivity of the instruments with which Nature has endowed the human body, judgment of riding-qualities is as varied and strange as the individuals themselves and may change from day to day, with the weather, the state of one's finances and one's degree of domestic tranquility, and is more critical when the car is not paid for, particularly when the last payment is due. The strange thing about riding-qualities is the disagreement among car users as to what is good riding-quality and what is not.

Physical and Mental Impressions at Odds

The specialists who deal with physical and mental impressions, either delicate or rising to the seriousness of a real injury, have given the very appropriate name "insult" to them, said the speaker, who remarked that many riding-qualities not only test our physical endurance but are an insult to our intelligence. These specialists tell us, he said, that two impressions spring from every insult, the one purely physical and the other mental. Thus, with riding-qualities we are always dealing with both physical and mental impressions, which influence the ever-changing decisions regarding performance. These impressions can be set down in three classifications, (*a*) pleasurable, (*b*) customary and (*c*) unpleasant or painful. The mental and physical impressions must be kept in mind, because they are always contending for the final decision with regard to riding-qualities.

Most persons, if asked whether they would enjoy riding on an absolutely smooth road, would say that it would be ideal. It might be very pleasant for awhile, so far as the purely physical effect was concerned, but it would become very monotonous and devoid of those elements of adventure, uncertainty and change that are the very soul of pleasure. The physical pleasure of riding is in mild exercise and the sensation of moving through space but the mental pleasure is in the changing scenes, the relief from customary sights and thoughts and the relief from the extreme boredom of living with oneself.

His Sensational First Ride

The perceptions that cause annoyance, fatigue or apprehension are all connected with the amount of fuss a car is making, said Mr. Horning, who in recounting his first real automobile ride to illustrate the point said in part:

> It was in a Northern runabout with a one-cylinder engine, short wheelbase, tiller steer, straight-back flat seat, and curved dash over which you could see the ground 6 ft. ahead. Your eyes were about 6½ ft. above the ground and there were no side doors and no windshield. The springs conspired with the short wheelbase and jumping engine to make the car bob up and down rapidly. With all these specifications, you will accept my statement that I took my fastest ride in that machine; to this day I believe it was 100 m.p.h., although I know the car could not go more than 15 m.p.h. . . . The vibration of the engine was heroic and, perhaps more than anything else, gave the impression of high speed when the engine was actually not turning over faster than 1000 r.p.m. The vibrations, which undoubtedly had an amplitude of ⅛ in., were so nerve racking that there was no need for a speedometer; speeding was not done or no one would have lived to tell the story.

In the cars of later days the amplitude of vibration has been greatly reduced and the speed increased, but the Bureau of Standards has found that vibrations of the seat of only 0.001 in. can be disagreeable and Mr. Horning said that he personally had determined that the most pleasant riding is done at an engine speed of not much more than 1000 r.p.m., as the fatigue grows rapidly at higher speeds. It is the number of impulses sent to the brain that tire and therefore it is important to keep both the severity and the number of impulses per hour down to the minimum.

Individuals Disagree as to Comfort

To illustrate the wide differences of opinion that may exist among various observers as to riding-qualities, Mr. Horning cited an incident that occurred in connection with the testing of two taxicabs that were the same in all particulars except that one had an engine made by his company and the other had an engine made by another company. Mr. Horning and his production manager, sales manager and the treasurer of his company went on the test

rides, which were to determine by feeling and impression which was the better job as to (*a*) power on hills, (*b*) acceleration, (*c*) freedom from vibration and (*d*) speed. Neither cab was equipped with an accelerometer or speedometer. Riding in the same machines at the same time and under the same conditions, it was impossible to get agreement in any respect as to the same points. This experience showed how difficult it is to determine facts by feelings. Yet it is in a world of such minds, which constitute the buying public, that the engineer is expected to come to a conclusion as to what is generally considered to be good riding-quality by the purchasers of his product.

To enjoy a car the passenger needs to have in mind some favorable preconception or ideal, said the speaker, and related another incident to bring out the point. A friend of his had for several years driven a certain make of fine car and liked it so much that he was using his third model, when he came to Mr. Horning one day and told him that another man who owned a car of the same make had called attention to the vibration at a speed of 31 m.p.h. Without realizing what effect it would have, Mr. Horning told his friend that this was the only thing he had noticed about the car except its good looks, and from that moment that car was junk to the owner; all he could observe about it was the vibration period at about 31 m.p.h., and he could not drive it without unconsciously dropping into that period. Thinking a new model might be free from this period, he bought one and the agent spent $500 trying to take out the much-reduced period but he could not remove the mental insult and it ended by the man's buying an entirely different make and type of car.

Once a defect or disagreeable incident occurs with a car, the customer becomes supersensitive to that one thing; on the second occurrence he becomes suspicious; and the third time he becomes irrational. Nine-tenths of the average complaints about a product arise from this mental attitude of automobile owners.

An exception to the general importance of comfortable riding-qualities is that when cars are used for business purposes, as the majority are, the most pleasing riding-quality is the ability to go where one needs to and get back, and men will put up with a bad collection of other riding-qualities for the sake of consistent performance, particularly if the first cost is low and the cost per mile is apparently low. Considerable physical punishment is endured in the belief that the car is the best that can be obtained for the money. The greatest fortunes have been made on cars that fit the pocketbook rather than the back and, while it is rather late to think of this, it may save some poor calculations even now.

Hard Steering Creates Sales Resistance

Coming down to specific features that affect the physical and mental perceptions when operating or riding in a car, the speaker referred to extremely hard steering as one of the most disagreeable things and said that a bad epidemic of this fault seems to have followed the advent of balloon tires and that it is undoubtedly cutting down the amount of driving by women and also by men. "I doubt whether balloon tires and nice soft riding can overcome the sales resistance that many cars are developing in their steering columns," Mr. Horning said.

It took the feelings and thoughts of thousands of women to impress the fact that cloth seats are more acceptable than leather upholstery. Many seats in late models are too wide for two persons and too narrow for three, and some owners of old cars will not buy new ones because of the narrow seats.

Many cars have a nasty trick of acting like a blanket drill, it apparently having been the designer's object to see how much oftener the rear seat occupant could hit the top than the seat. There is no excuse for this, for the springs and the seats can be made so that bumps will not throw the passengers through the top but they will be held down to the seats.

Pleads for Comfortable Truck Seats

With reference to seats on trucks, Mr. Horning pleaded with every truck company and every owner of trucks to do everything in their power to make the drivers' seats more comfortable and said he could imagine no more effective way to increase the efficiency of the drivers than to give them some comfort. His strictures applied to the cushion as well as the backs and the general posture, and he said that he did not believe it possible to overestimate the fatigue, suffering, loss of health and efficiency and the number of accidents that arise from the bad seats, as trucks must be mounted on stiff springs and every road shock is communicated to the driver's body, up the spine to the brain and through every fiber.

Many brake pedals have the foot clip on the side next to the clutch pedal instead of on the right side of the foot pad, which he was convinced was bad practice, as the foot is likely to slip off, as happened to him one day when turning into a gateway and resulted in carrying away the gate-post. A lamentable lack of means for keeping the foot throttle steady also exists. With the bobbing due to balloon tires and the peculiar springing, the instability of the foot on the throttle starts the engine acting in tune with the bobbing of the car until "one feels that he is riding on the dappled horse of the whirligig." Nine out of ten foot throttles are responsible for some bad riding-qualities, according to the speaker, who said:

> If some engineer with a slight knowledge of anatomy would draw a seat with a man's leg on the throttle and then draw a line from the knee joint down through the ankle and extend the line to the floor-boards, he would, with a little experimenting, locate a pivotal point which would be neutral to the movement of the driver's body and yet allow the throttle to be restful to the foot, easy to operate accurately and a comfort on long drives.

Eliminate Synchronous Vibration of Parts

At the risk of overemphasizing a great fault, Mr. Horning referred to the synchronizing of various parts of the chassis with the engine as being the cause of many ragged nerves. Vibrations of the engine, which can and should be minimized, but cannot be wholly eliminated, can be isolated from the chassis and the whole machine designed so that no part will have a vibration period above the maximum slow speed of the engine and its maximum high speed. In this connection he stated:

> The time is here to design a car with a tuning-fork, particularly as regards the gears, pedals, brake and gear-shift levers, radiator rods, foot-board brackets, lamp brackets, steering column, brake rods, doors and door glasses and so on. Every part that vibrates has its own period. The amplitude may be in proportion to the out-of-balance of the part but the vibration can be entirely suppressed with proper design. It is astonishing to see how effectually this can be done by merely changing the period of responsive vibration to an outside influence. Throughout the chassis there are innumerable parts that could be stressed to four times that allowed but must be made stronger for reasons of elasticity, and if the problem is approached from this standpoint, real progress can be made.

Many vibrations blamed to engines are due to the universal-joints and the driveshaft, which are the cause of some of the most annoying and common vibrations and the most difficult to suppress. The clutch comes in the same category. Builders of first-class cars can do nothing to improve the riding qualities of their cars that will be more effective than a careful job of balancing the flywheels and the clutches. Mr. Horning said:

> A striking example of what can be accomplished came to attention in the case of a car that was put through a clinic and completely balanced from crankshaft to axle shafts. Not only was it wonderfully improved in riding-qualities, but the miles per gallon

were increased beyond the extravagant claims of carbureter manufacturers.

Many phases of vibration are being considered by the Riding-Qualities Group of the Research Committee and by the Bureau of Standards. Vibration periods that may result in undesirable riding-qualities lie between 70 per min. and 9000 per sec., which take in the oscillation period of the chassis and the range of audible sound.

The High Cost of Acceleration

The speaker referred disparagingly to door handles and other hardware that have a beautiful design and finish but have sunk low in utility, the doors flying open and the glass breaking when the doors are slammed shut sufficiently hard to latch them securely. He left springs "to the mercy of the divine genius of purchasing agents" and commented favorably on balloon tires and four-wheel brakes, which he said were here to stay, although they brought the problems of bobbing and shimmying. He closed by saying that Americans pay a high price for the pleasurable sensation of acceleration and that he had estimated that at least 22 per cent of the fuel consumed is due to toting around an ability to accelerate and the liberal use of that ability. On this point he remarked:

> The English like acceleration on second gear, with the illusion that results from the noise of the gears and the bumpiness of the car, which accentuate the impression of great doings. The Americans take it on high, and this leads to our extreme rear-axle ratios. We are sacrificing smooth engine operation on the average for great acceleration and hill-climbing ability. A great improvement is awaiting development in which high gear-ratios can be had without fourth-speed growls.

DATA ON FLAT-RATE SERVICE-SYSTEMS

Details Determining Successful Servicing Presented to New England Section

Consistent efforts to control service-station work, by including specified prices for all labor and all material when quotations are made to customers, are producing satisfactory results according to two papers presented at the meeting of the New England Section held on March 18 at the Engineer's Club in Boston. The first was by H. T. Pierce and P. U. Holloway, assistant service manager and estimator, respectively, of the Donovan Motor Car Co., Studebaker distributors for New England, and the second was delivered by Frederick P. Rudolph, of the Cadillac Motor Car Co., Boston.

In presenting an outline of the flat-rate system adopted in 1922 by the service department of the company he represents, Mr. Pierce said that use is made of a card-index system in the estimating office and in the main service office. In it, 8000 master and 12,000 parts operations are printed on index cards and filed in the index book that accompanies this particular card-index system. On each operation-card is a complete record of the amounts of time and material to be charged to the customer, and of the amount of pay due the mechanic. The different operations are divided into 26 groups, such as engine, clutch, transmission, rear end and the like, and each group is lettered; the first card in each group is numbered 1.

The inspectors are men who have been trained in the repair shop and who have worked their way through the different departments successively. This assures having them competent as regards the mechanical construction of the car this company distributes. Five such inspectors are stationed at the entrance to the main service-station to meet the customers and write out the repair orders. They are not allowed to quote any flat price to customers, because estimators are employed specifically for that purpose. It has been found very important to train the inspectors to a degree that enables each man to write out needed operations in a form such that they can be thoroughly understood by the foreman and by the shop mechanics, and so that the jobs can be "flat rated" properly.

Four differently colored separate sheets, each carrying the order number, constitute the job order. A white copy goes to the main office, a pink copy to the estimators' office, a yellow copy to the customer and a tan-colored hard-finished copy to the repair shop. On the back of the white copy, space is provided in which to post all the material and all the labor that is used in the different operations. The customer's bill is made out from this copy. The pink copy is filed in the office of the estimators, for future reference regarding any additional work on the job order and for information concerning previous job orders. The yellow copy given the customer affords him means for information and record. A customer's claim-check is also attached to the yellow copy; this he tears off and presents to the cashier when he returns for his car. The hard-finished copy of the job order is sent to the repair shop with the car and becomes the "shop job-order."

After the inspector has written out the repair job-order, the customer brings the order to the window of the estimators' office and, there, each operation is given its proper number and flat-rate price. The car is then taken to the repair shop by the garage men and turned over to the shop foreman. The white copy of the order is sent to the main office by the estimator.

When the white order reaches the main office, a clerk posts the amount of money due the mechanic on each operation; then, he files this copy with the other job orders that are awaiting requisitions and mechanic's assignment-tickets. The shop foreman makes out an assignment ticket in duplicate for the different operations he may see fit to have some certain mechanic perform. One copy is kept for reference; the other is sent to the job-order clerk. On receiving this copy of the assignment ticket, the clerk posts the mechanic's name and number on the operation, according to the shop foreman's assignment.

In estimating a repair job-order, Mr. Pierce explained that some of the operations often conflict with one another. But in any case one of the operations becomes a "parts operation"; in other words, it is performed in conjunction with the "master operation." For example, suppose that operation No. 1 is to take-up and refit the main and the connecting-rod bearings and that operation No. 2 is to install new wristpins. No. 1 would be the master operation and would be flat-rated at the master-operation price. No. 2 would be figured as a parts operation with refitting of main and connecting-rod bearings, and this would be, approximately, a 2-hr. job. Otherwise, as a master operation to install six wristpins, it would constitute a 6-hr. job.

If, during the course of repairs, additional work is found necessary, the shop foreman sends a written report to the estimators' office that explains the condition found. The estimator telephones to the customer, and explains the circumstances and requests authority from the customer to perform this work at a flat-rate price. If such authority is granted, the estimator writes out a supplementary order, pricing it and numbering it in the same manner as for the original job order; then, the copies are sent to the different departments, there to be attached to the original order copies.

Mr. Pierce said further that his company has found this system to have decided advantages, compared with the former time-and-material system. He stated that the shop mechanics turn out almost double their former volume of work, and that each job is guaranteed to the company by the mechanic who does the work. Any "come-back" work that is reported within a reasonable time after repair work has been done is done again by the mechanic; no pay is given the mechanic for come-back work, and no charge is made for it to the customer.

Prices to Include Labor and Material

Until such time as the service-station price-quotation includes both labor and material, misunderstandings with the customer regarding prices will continue, according to a statement made by Mr. Rudolph while presenting his paper. To make a definite-price plan successful, the average amount of material required to complete a given operation must be decided upon. If careful judgment is used in selecting the

material to be used at a stated price and it later becomes necessary to sell additional material to the customer, that is accomplished more easily than if it had been combined with the first sale. But when additional material is charged for, credit should also be allowed the customer for material not used.

In Mr. Rudolph's opinion, the definite-price plan should be presented to the workman in the shop on a basis such that he is convinced of having entered into business for himself, except that the company pays the rent and furnishes tools, light and heat. As a business man, he then realizes that faulty work of his own should be made good without extra charge. This responsibility for the good quality of his work and the fact that any special effort he makes increases his earnings, will make the definite-price plan effective.

Information needed to sell maintenance operations should be as compact and as available as it is possible to arrange it so that salesmen can sell any one of the repair operations from any part of the station. For quick reference and also to utilize advertising value, Mr. Rudolph suggests having within view of the customers and the salesmen a large square of canvas on which the most frequent operations and their prices are placarded. The sign also should announce that credit will be given for all unused material.

In the system advocated by Mr. Rudolph, the master copy of the control is bound in book form and has only one operation on each sheet. It includes all the operations in the definite-price program; and he claims this has many advantages, compared with the card-index system. Each operation in the master book must be defined very clearly regarding the type of car to which the operation applies, the operation number and name, an outline of the work to be done, the divisions of labor and of price, the symbol number, name, price and cost of material allowed and the total or "definite" price of the operation. According to what portion of the car they represent, the various operations should be separated into groups, allowing say between 100 and 200 operations per group.

Recommending that a copy of this master book, with cost and selling prices omitted, be placed in each mechanical department and made accessible to the workmen for ready reference as to time allowances, nature of the work to be done, its sequences, the price the workman is to receive, the symbol numbers and the names of the materials allowed, Mr. Rudolph said that additional copies of this book, containing sales prices, also should be located in the superintendent's and in the service sales department's offices as well as in each stock room. For stock-room use, each book should quote the cost and the selling prices of all material. Another copy, including all prices, is used for checking and control purposes at the time each job is closed. All changes in labor charges, symbols, prices and routine are made first in the master copy of the control book and then in all of the other copies used in the station.

In this system, one timekeeper can compute the earnings of 100 men up to 5:30 p. m. daily, enter them on the payroll sheet and pay off any workman immediately thereafter. Postings to the payroll sheet are continuous throughout the day, thereby releasing time tickets for entry practically as soon as the workman completes his work. The workman is not paid until the operation is completed in a manner thoroughly satisfactory to the foreman. At an average of 100 service jobs per day, invoices can be mailed to customers not more than say 3 hr. after the completion of the work in the shop. The last step in the process is an analysis of all operations. This should be done by someone who is competent to report upon and to initiate an investigation of all irregularities.

In the discussion that followed the presentation of the papers, attention was called to the fact that the term "definite-price plan" seems a more specific and appropriate name for this system than does the term "flat-rate system." The questions and answers related chiefly to minor details of this method of servicing.

HOFFMAN TELLS OF AIR-CLEANER TESTS

At the Los Angeles group meeting of members of the Society, held on March 27, the topic of the evening was the Efficiency of Air-Cleaners, as shown by the series of tests conducted during the last 2 years by Prof. A. H. Hoffman, of the agricultural engineering division of the University of California, who made the address. His talk, which was illustrated by many lantern slides, was largely a presentation of the facts and data given by him at the Annual

SCHEDULE OF SECTIONS MEETINGS

APRIL

1—MILWAUKEE SECTION—Lubrication of Gasoline Engines—H. L. Horning
2—DETROIT SECTION—Address by C. F. Kettering
7—BUFFALO SECTION—Freight Transportation—Major Elihu Church
8—DAYTON SECTION—What Public Service Utility Companies Want in an Automobile
NEW ENGLAND SECTION (Boston)—The Application of the Duco System for Finishing of Motor Cars —J. J. Riley
9—INDIANA SECTION—Electrical Instruments for Automotive Research—J. H. Hunt
14—PENNSYLVANIA SECTION—Modern Refining Processes—John D. Gill
16—DETROIT SECTION—Sheet Metal—F. R. Pleasonton
METROPOLITAN SECTION
17—CHICAGO SECTION—Design of Diesel Engines—Philip L. Scott
20—CLEVELAND SECTION—Production Meeting. Symposium of Practices in Machining Connecting-Rods by representatives of local automobile manufacturers
24—LOS ANGELES GROUP—Los Angeles Major Traffic Plan—David R. Faries
Can Motorbuses Relieve Congestion?—Phil Harris
WASHINGTON SECTION—Around the World Flight—Lieuts. Leigh Wade and Leslie P. Arnold
30—SAN FRANCISCO GROUP—Six-Wheel Trucks—Ethelbert Favary

MAY

6—MILWAUKEE SECTION
12—PENNSYLVANIA SECTION—Trip to Naval Air Station, Lakehurst, N. J., with talk by naval officer
19—BUFFALO SECTION

Meeting in Detroit in January, which the Southern California members of the Society were unable to attend, and included final results derived from tests made between June and December, 1924, which were covered fully in the paper[1] by Professor Hoffman. The Los Angeles address was of particular interest to the group members because the tests were made on the road and in the laboratory in California.

DISTRIBUTION

Automobile Merchandising Systems Described at Metropolitan Section Meeting

RAY W. SHERMAN

What factors influence the flow of merchandise? Why is one car a success, another a failure? How does the system of distribution affect the price that must be paid by the consumer? These and other questions dealing with the distribution of merchandise in general, and with that of automobiles in particular, were ably discussed by Ray W. Sherman, editor of *Motor*, before the monthly meeting of the Metropolitan Section, held at the Hotel Empire, New York City, on March 19.

The purchase of automotive products, said Mr. Sherman in part, involves an expenditure by the American people of approximately $50,000,000,000 per year, or about 10 per cent of the total business done in this Country. In marketing any product four factors enter, (*a*) the goods, (*b*) the customer, (*c*) the salesman and (*d*) the sale. Under these headings can be grouped everything connected with selling.

Pyramidal Form

As applied to the automotive industry, the distribution assumes a pyramidal form consisting of five groups. At the apex are the raw materials, including the parts, of which the products are made. In the second division is the manufacturer of the product, and with him is included the engineer. The third division comprises the wholesale or jobbing distribution; the fourth, the retail distribution, or the persons coming into contact with the public; and the fifth, the public itself, or the consumers. This layout also includes accessories, whether they be tires, batteries, parts or anything else. The retailers include car dealers, garage men, accessory stores, battery men, electrical stations, tire stores and the rest. In the last group are the persons who own 15,500,000 passenger cars and 2,200,000 commercial vehicles, a total of 17,700,000 vehicles at present in use.

Manufacturer's Agent

Under this classification, said Mr. Sherman, would be included the manufacturer's agent, who functions as a sales department of a factory, selling usually to the wholesalers. The specialty jobber and the battery service distributer should be included with the wholesalers. When a manufacturer sells directly to the consumer, he is simply taking over the functions of the wholesaler and the retailer, because these functions must be performed.

A manufacturer may make the finest parts but of what avail is it if they cannot reach the consumer? In general, continued Mr. Sherman, the manufacturing cost of a commodity is about one-fifth of the retail price. If a piece of merchandise tries to push its way through the distribution system and fails, it begins to back up. Then begin periods of overproduction and of business disaster. Marketing merchandise is like trying to join a club, the acceptance of the merchandise by the Consumer Club being the object sought; the blackballing of merchandise that has failed to receive favorable recognition by consumers has cost large sums of money.

A product must travel from the top of the pyramid to the bottom at the lowest possible cost, for if the trip is made too expensively, someone else will find a way to do it more cheaply; the product will be outsold and will never reach the consumer goal.

A. P. Sloan, Jr., has stated:

> Any man who has attained the age of 25 or 26 years has just about outgrown his boyhood days, and if he is ever going to be a man, he is a man at that time.

The automotive industry is now in that position, added Mr. Sherman.

Law of Supply and Demand

Because the automotive industry has advanced steadily with few setbacks, some persons have believed that certain fundamental laws could be ignored, among them the law of supply and demand. Because the world has been waiting for transportation and this is now supplied to it, the idea has prevailed that supply is the only essential and that demand will take care of itself.

That the same law of supply and demand that controls drugs, cigars, and other commodities also controls the automobile business is evidenced by the fact that at least 500 manufacturers of automobiles who have disregarded this law have failed to get consumer acceptance and have been put out of business. At last year's Automobile Show in New York City, 66 makes of automobile were exhibited; at this year's Show, there were 52. How many will there be next year? Whether the number will continue to be 52 will depend upon the decree of the consumer. His decree henceforth will be even more effective, as the so-called saturation-point is approached.

It was not the manufacturer of parts seeking a market who created the parts jobber, said Mr. Sherman; it was the demand of the consumer that parts jobbers be created. If the parts jobber functions to the satisfaction of the consumer, he will be a factor in the field; if not, he will pass out of the picture.

Radio has recently challenged the automobile industry. The automobile spent 12 or 15 years getting started, because it was a rich man's toy. The radio has come in overnight because it is the toy of all classes and appeals to the inventive genius of millions of boys from 8 to 20 years of age.

Survival of the Fittest

Many cars have attained a certain success and then suddenly passed out, continued Mr. Sherman. One car with a tilted radiator failed to meet with popular approval, a small boy being responsible for preventing one sale by inquiring "Oh, mister, how did you bump your radiator?" No amount of sales talk could convince the public that it wanted a tilted radiator. The question is not what the engineer would like to build, but what will induce the public to part with its money. A successful automobile engineer is an engineer who builds a car in the way the public wishes it built.

In the discussion, the question of sales surveys was brought up by H. G. McComb. To this Mr. Sherman replied that companies are divided into three groups of those that (*a*) really make sales surveys, (*b*) think they are making them and (*c*) make none. The General Motors Corporation has just finished one of the greatest surveys ever made and has estimated the probable sales of automobiles for each year until after 1930. Some other companies have made less complete surveys.

Surveys

One difficulty, suggested N. G. Shidle, is not so much in a company's not attempting to make a survey as in not believing the results after the survey has been made. If the survey does not come out as the sales manager desires it,

[1] See THE JOURNAL, March, 1925, page 367.

and in accordance with the plant capacity, the results of the survey are ignored.

Replying to other questions, Mr. Sherman said that, when a company is not large enough to maintain a complete distribution system of its own, some of the steps may be combined in a manufacturer's agent. Sub- or semi-jobbers in reality fit into the jobber classification. Advertising is beneficial if an article is sound and salable; but if not, advertising will not produce repeat orders. No amount of advertising, he said, could make him believe that he liked fried bananas, for he had tried them once.

Taxicabs and machine-tools are examples of products that are sold directly by the manufacturer to the consumer, but their fields are limited.

DIE-CASTING AS A PRODUCTION ASSET

How Intricate Dies Speed Production Is Explained to the Detroit Section

MARC STERN

An historical review of die-casting and outlines of present die-casting practices were presented to those who attended the Detroit Section meeting, held on March 19, by Marc Stern of the Doehler Die-Casting Co., Brooklyn, N. Y., and by B. F. Lewis and R. L. Shepard of the C. B. Shepard Co., Detroit. The subject of die-casting was covered comprehensively, and a large amount of specific information was conveyed. Mr. Stern said in part that because many different methods of producing castings exist outside the sand-casting realm, some confusion prevails as to the exact definition of the term die-casting. Such castings may be produced in metallic or in non-metallic long-life molds, or in combination with destructible cores. They may be filled by gravity and known as "permanent-mold castings"; or by centrifugal force and known as "centrifugal castings"; or by filling the mold by gravity and, after the outer skin has become chilled, pouring out the excess liquid metal. The last named are known as "slush castings." On the other hand, a "die-casting" may be defined as a casting formed in a metallic mold or die, from metal subjected to mechanical or gaseous pressure while in the molten state.

It is important to contrast this last definition with so-called "pressed castings" or drop-forgings in which the pressure is applied while the metal is in a plastic or a semi-plastic condition that makes impracticable the coring of side holes. In die-castings, the metal being liquid, the pressure is practically uniform in all directions, and complicated coring of holes and of side cavities is therefore easy of accomplishment. The molten metal, coming into contact with the comparatively cold surfaces of the mold, chills immediately and the feed of the metal is maintained under full pressure until the die-casting has solidified completely. The sudden cooling forms a smooth hard skin on the surface with a comparatively coarser structure at the center of the walls.

DIE-CASTING ALLOYS

Saying that alloys of comparatively low fusing-points are best adapted to the die-casting process, Mr. Stern divided them into the following groups:

Tin-Base Alloys.—Contain 60 to 90 per cent of tin, 3 to 7 per cent of copper and 3 to 7 per cent of antimony. Alloys having the lower tin-content contain 10 to 25 per cent of lead. The maximum fusing-point is at 450 deg. fahr.; the tensile-strength, about 8000 lb. per sq. in. These alloys produce castings of fine sharpness and finish, but the high cost of tin largely limits their use

Lead-Base Alloys.—Contain 80 to 95 per cent lead, alloyed with antimony alone or in combination with tin up to about 10 per cent. The maximum fusing-point is 600 deg. fahr.; the tensile-strength, about the same as that of the tin-base alloys, or about 8000 lb. per sq. in.

Zinc-Base Alloys.—Contain 88 to 95 per cent zinc, alloyed with tin and copper or with aluminum and copper. The fusing point is about 780 deg. fahr.; the tensile-strength varies from 16,000 to 35,000 lb. per sq. in., depending upon the grade and the relative proportion of the elements. They resemble cast iron, being hard and brittle under blows

Aluminum-Base Alloys.—Contain about 90 per cent aluminum, alloyed with copper, nickel and silicon. The fusing point is 1150 deg. fahr.; the tensile-strength, 18,000 to 21,000 lb. per sq. in. Despite the fact that aluminum alloys present difficulties in handling, such as high shrinkage and a great affinity for ferrous metal, of which pots and dies necessarily must be made, they are the only high-melting-point alloys to achieve commercial success

Concerning the design of die-castings, Mr. Stern believes that the designer of a new device requiring their use should consult specialists in this line while the entire design is still on paper, so that the functional as well as the casting production features can be coordinated properly. He says that the accuracy of a die-casting depends upon the wear of the die and the shrinkage of the alloy. Flashes of metal attached to die-castings as they leave the die and known as "fins" can be kept to the minimum when the dies are constructed substantially, lubricated properly and kept clean on their surfaces. In soldering zinc-base die-castings, the main precaution needed is to maintain the temperature below 250 deg. fahr. to prevent sweating out the tin element.

Mr. Stern also considered in some detail the polishing, enameling and electroplating of die-castings, the methods used for die-casting and the applications and limitations of die-castings in general. He concluded by saying that die-casting is merely another manifestation of the tendency of the times to permit the skill of the trained operative to be used repeatedly by other operatives who are less skilled. The skill of the tool maker, embodied in the construction of intricate dies, is used by the unskilled worker in producing and reproducing castings ranking high in quality and in quantity.

THE PLATING OF DIE-CASTINGS

Characterizing the successful application of decorative finishes to die-castings as a formidable problem, Mr. Lewis went on to say that, although this is not a matter of great concern on die-castings used simply for mechanical purposes, it constitutes a very important factor in the production of fittings for the interior of inclosed automobile-bodies because of difficulties found in plating them satisfactorily.

Aluminum and zinc are most commonly the main constituents of alloys used for die-casting, with other elements added to modify the physical properties, and zinc usage predominates where great physical strength and resistance to corrosion are not required. On castings of simple design and regular contour, plating does not involve unusual difficulty; but, on pieces of irregular shape having deep recesses, plating is difficult and especially so when nickel is to be deposited.

Mr. Lewis said further that when a die-casting of zinc-base alloy is suspended from the cathode in an ordinary nickel-plating solution when no current is flowing, nickel deposits galvanically upon the piece in the form of a dark non-adherent coating; and that this is the same reaction as that which occurs when coatings are plated with too low a current density. Then, the nickel deposits normally on exposed portions of the piece, but black streaks alone appear in the recesses. If the current density is increased to the point at which the nickel deposits normally in the recesses,

the deposit on the exposed portions usually will be dark and rough. Since no really satisfactory medium value between these two extremes in an ordinary solution has been found, the only alternative is to change the composition of the solution to produce the special conditions required for plating die-castings. Until recent work was done by research chemists at the Bureau of Standards, it was not known that the one factor most conducive to making good nickel deposits on zinc, all other conditions being normal, is high cathode polarization. This property of nickel-plating solutions can be controlled by using certain chemicals such as sodium citrate, sodium sulphate and the like.

The efficacy of sodium citrate in solutions for nickel-plating zinc has long been recognized by platers, but the reason for its beneficial effect has been rather obscure. Now it develops that sodium sulphate is even more beneficial, and that it has the advantage of being much less expensive. This salt is added to nickel solutions of normal concentration that contain some conducting salt such as, preferably, ammonium chloride. As high as 3 to 4 lb. of sodium sulphate to 1 gal. of solution can be used to advantage. In a solution of this composition, zinc-base die-castings of intricate design can be plated at comparatively low current densities without danger of streaking or burning.

No necessity exists, Mr. Lewis said, for preliminary "striking" of the work with copper or brass as is often done to assure satisfactory deposits in ordinary nickel solutions, and the solution can be used at any temperature from 60 to 110 deg. fahr. provided the acidity is adjusted accordingly. Additional agents for brightening the deposit can be used, and objects made of steel or brass can be plated, as well as die-castings. A good nickel deposit is the basis of practically all finishes on die-castings; consequently, if die-cast articles are nickel plated properly, any other metal such as gold, silver and the like can be applied subsequently. Given a sound homogeneous casting, properly polished and prepared, no reason exists why die-castings cannot be plated as satisfactorily as is true for any other material.

DILUTION, ITS CAUSES AND MEASUREMENT

Washington Section Has Interesting Discussion, Followed by Demonstration

What is crankcase-oil dilution? Why does it occur? What can be done about it? Are its effects entirely evil? To what extent has it been studied? What methods have been evolved for measuring dilution? These are some of the questions that were discussed at the meeting of the Washington Section on March 6, when S. W. Sparrow and T. S. Sligh, Jr., both of the Bureau of Standards, spoke on the subject of crankcase-oil dilution.

Mr. Sparrow defined crankcase-oil dilution as the addition to lubricating oil of some liquid which will mix completely with it and reduce its viscosity. He pointed out that this definition excludes from the discussion the effect of the addition of water to lubricating oil, because water either does not mix with the oil or else forms a sludge which flows less readily than the lubricating oil.

What Causes Dilution?

After a brief outline of the investigation which gave rise to the present intensive study of crankcase-oil dilution, the causes of dilution were discussed under the following divisions: (*a*) too-cold operating-temperatures and too-cold cylinder-wall temperatures, (*b*) too rich a mixture and (*c*) fuel of low volatility. Mr. Sparrow emphasized the fact that the dilution taking place in the operation of an engine under conditions of steady speed and load is less than that which takes place during the starting period, because the conditions at the time of starting are considerably different from those during normal operation.

Cures that were mentioned include (*a*) using a lean mixture, (*b*) shortening the starting period by various expedients such as covering the radiator and (*c*) operating at a reasonably high temperature.

Relative to the advisability or inadvisability of getting rid of dilution, Mr. Sparrow stated that the whole subject hinges upon the matter of lubrication and what particular viscosity of the oil is necessary to give satisfactory lubrication. He made a distinction between the usual idea that the primary object of lubrication is to decrease the effort or force required to move one surface over another and the idea, believed to be more nearly correct, that the function of lubrication is to provide some substance between those two working surfaces which will keep them apart whenever they are in motion. The property which keeps the substance there is usually defined as viscosity. Mr. Sparrow pointed out that the viscosity which is desirable under certain conditions will be undesirable under other conditions. For example, under a given load, a more viscous oil will be required to keep the working surfaces apart if dust is present. Also, a somewhat less viscous oil is desirable, or even necessary, for winter operation than for summer operation.

In conclusion Mr. Sparrow stated that dilution is not objectionable because diluted oil is of this or that viscosity, but because dilution implies a change of condition; it means that if conditions are right at one time, they will be wrong later. He expressed the belief that the time would come when engine designs would be such that comparatively little change in oil would be required from summer to winter and that under those conditions it would be necessary to get rid of what would then undoubtedly be an evil, namely, crankcase-oil dilution.

Evaluation of Dilution

Touching upon the chemistry of fuels, Mr. Sligh spoke briefly upon the mechanism of dilution and described a vacuum distillation transition method of dilution evaluation which is useful when high accuracy is very desirable. This method was described in the paper[1] that he presented at the Annual Meeting in Detroit last January.

A Simpler Method Developed

Because the apparatus is rather complicated that is needed in the vacuum distillation transition method, and for other reasons, a simpler method has been devised which is somewhat less exact, the results being accurate to within 1 or 2 per cent, instead of 0.1 or 0.2 per cent. In the simpler method, according to Mr. Sligh, advantage is taken not of the change in temperature in passing from the naphtha to the oil, but of the change in viscosity.

The diluent goes from the condenser into a funnel which has a capillary tube on its lower end through which the diluent flows into the graduate. As long as the naphtha or the heavy ends of the gasoline are being distilled, the substance which flows through the capillary tube is very fluid and the average head on the capillary is low, that is, only about ½ in. of liquid is necessary to cause the flow which will take care of the rate of distillation.

Later, as the transition section of the distillation curve is reached, the rate of distillation drops off, as the temperature rises, and the head begins to drop down very abruptly. It may even drop so that bubbles will be flowing through the tube with the liquid. Then the more viscous oil will begin to come over, the head rising very rapidly, because viscous oil cannot pass through the capillary as fast as the distilled. The volume in the graduate, at the time of this rapid rise, represents the volume of diluent in the original charge. This method requires about 10 or 15 min. to run a test. It is designed for the average man or the operator of a fleet of vehicles who is not interested in knowing whether he has 20, 21 or 22 per cent of dilution but who would like to know whether he has 10 or 20 per cent. Relative to the amount of dilution that might be expected, Mr. Sligh said that 20 per cent is rather usual for the present weather.

Mr. Sligh concluded his talk by giving a demonstration of the capillary funnel method, measuring the dilution in several samples of used oils that had been brought in by members of the Section.

[1] See The Journal, March 1925, p. 358.

Publicity for Meetings

One feature of the meeting was a report by Vice-Chairman Warrington of the plan of the Associated Engineering Clubs of the City of Washington, whereby the nine engineering societies with sections or chapters in the District of Columbia will publish a bulletin, disseminating news as to the activities of the various sections involved. The automotive engineers will cooperate in publishing this joint bulletin, but will also publish their own bulletin, as formerly.

Section Officers Nominated

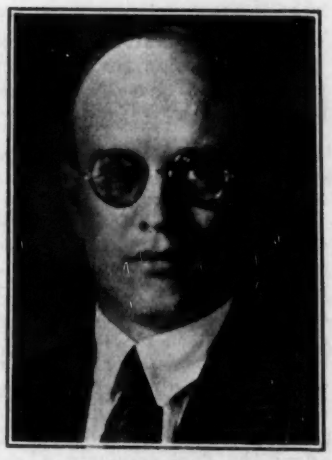
The following nominees were announced by the nominating committee for next year, the election to be held at the April meeting: Stanwood W. Sparrow, chairman; Paul B. Lum, vice-chairman; Robert Kohr, secretary; and Conrad H. Young, treasurer.

April Meeting Plans

The round-the-world flight will be the subject of the April meeting. Lieut. Leigh Wade and Lieut. Leslie P. Arnold will tell of their experiences, illustrating their talks with slides, and a most interesting meeting is anticipated.

AUTOMOBILE BRAKES

Air-Pressure and Vacuum Booster Varieties Are Discussed by Detroit Section



H. D. Hukill

Airbrakes for automobiles one operating under pressure the other under vacuum, occupied the attention of the Detroit Section at its semi-monthly meeting on March 5. The features of the pressure airbrake were presented by H. D. Hukill, whose paper[1] was printed in full in the March issue of The Journal; those of the vacuum booster brake were outlined by Caleb S. Bragg.

A vacuum booster brake, said Mr. Bragg in part, is fastened to the chassis and is operatively interposed in the brake-rod between the brake-pedal, or the manually operated lever, and the brake equalizer, and is connected to the intake-manifold by a pipe in which is a check-valve.

The vacuum exerts a suction on the face of the piston, while air pressure is exerted on the rear side. After an application of the brake, the piston will remain stationary, if it carries a balanced load, or will automatically try to find this balanced condition, if the braking load should vary, or the accelerated movement of the piston should exceed the load.

The design of the valve allows a construction that will (*a*) always submerge the cylinder in vacuum when in the "off" or "at rest" position; (*b*) admit air to the rear of the piston for the application of the brake; (*c*) exhaust the air thus admitted so that the cylinder will again be submerged in vacuum and allow the brake to release itself, and (*d*) admit air to the front of the piston and suction to the rear, for power or quick release.

Application of the Vacuum Brake

When the operator applies the brake, said Mr. Bragg, atmospheric air is admitted to the rear of the piston, while vacuum continues to be maintained at the front. When the operator gradually releases the brake, as in continued braking on long grades or in traffic, the higher pressure at the rear of the piston is connected with the source of suction and also with the lower pressure in the cylinder in front of the piston, the result being a reduction of pressure at the rear that was necessary to apply the brake, and an equalization of the pressures on both sides of the piston that allows the piston to be readily withdrawn under the load of the applied brake, without admitting atmospheric pressure to the cylinder in front of the piston. A subsequent application of the brake, before the piston has reached its neutral position, shuts-off the suction and admits atmospheric air to the rear of the piston, without exhausting an appreciable volume of air into the intake-manifold, as is the case in the original application of the brake. When the operator has finished braking and has removed his foot from the brake-pedal, a retracting spring forces the valve-actuating rod rearward and connects the rear side of the piston with suction and the front face with atmospheric pressure, so that the brakes are released under power.

The valve-timing allows the brakes to be applied and released continually under normal driving-conditions by merely admitting to the rear end of the cylinder and withdrawing from it relatively small quantities of atmospheric air, while the forward end is continually submerged in vacuum.

As the retracting spring for the valve-actuating rod and for the foot-pedal is located between stops fixed on the piston-rod and the hollow valve-actuating rod, the slightest effort of the operator to overcome the retracting spring is applied directly to the brake through the piston-rod. The piston will always be held against the end plate, which is the stop for the brake mechanism in the off position, if the load on the brake, when in the off position, is greater than the strength of the retracting spring. In cases of emergency, the operator can at any time apply his physical force to the brake, in addition to the pressure exerted by the brake cylinder.

Moderate Power Desirable

Although the vacuum can be made sufficiently powerful for any automotive vehicle, continued Mr. Bragg, it is recommended that a size of cylinder should be used having only enough power for an ordinary stop and that emergency stops should be made by the addition of physical force; otherwise the sense of "feel" will be destroyed, which, in general, is similar to that of a two-wheel mechanical brake.

In comparing the relative merits of the vacuum and of the pressure braking systems, Mr. Bragg considered (*a*) their ease of control, (*b*) their facility of operation, (*c*) the source of power and (*d*) the cost.

Foot operation, he said, offers nothing new, and an operator may take out any car so equipped without fear of disastrous results; whereas, manually operated brakes require familiarity with their use. An important objection to manually operated brakes is the fact that too many other things must also be done with the hands, such as signaling the course one intends to take, sounding the horn and changing the gears. Under these conditions the use of a foot-brake is almost imperative.

Among the operating advantages of the vacuum brake, continued Mr. Bragg, is its construction, which, while sufficiently strong to withstand the full physical power of the operator in emergencies, avoids the disadvantages of overpowerful separate braking that frequently causes unintentional skidding and unnecessarily sudden stops, which result in discomfort to passengers, shifting of the load and the accompanying wear and tear on the tires and on the vehicle body. Because it is capable of making only an ordinary stop, an emergency cord, which can be operated in case the driver becomes incapacitated, will cause the car to stop, but without the abruptness that sometimes is productive of accidents. The vacuum brake, being governed by the amount of travel of the foot-pedal and the actuating piston, is more positive than a separate braking system, because it does only the amount of work that is expected of it. It has no ailments peculiar to itself, no delicately adjusted valves to stick or freeze, but an ever-present and constant source of power.

[1] See The Journal, March, 1925, p. 283.

Any mechanical failure is immediately noticeable to the driver, who is thus forewarned of danger.

Vacuum Always Present

The power of the vacuum in the intake-manifold, plus the physical power of the operator, is ample and is more reliable than is that of an auxiliary motor, for a vacuum is always present in the intake-manifold when the engine is running and the throttle is closed; moreover, the engine cannot stop while the car is in motion, if the clutch and the gears are engaged. The vacuum, too, is not subject to changes of temperature, requires no attention and its efficiency increases with the speed of the vehicle; an average engine when idling maintains a vacuum of between 18 and 20 in. of mercury, but, when the speed of the engine increases, the vacuum becomes as high as 25 in. The braking power consequently increases with the speed of the car.

In cost, the vacuum brake shows to advantage, because the manufacturing cost is low, the maintenance almost nothing, as there are almost no wearing parts and no expense for power. When the source of power of the vacuum brake fails, it is because the engine does not function properly; hence, the vehicle could not be used anyway.

When used with four-wheel brakes, concluded Mr. Bragg, a double piston is employed that doubles the power of the brake-cylinder without increasing its bore, while adding only a few inches to its length. When fitted to six wheels, another air-chamber is added with another valveless piston mounted in tandem with one of the other pistons.

Brake-Lining Material

Replying to a query as to the composition of the liners of the brakeshoes and the brake-drum, Mr. Hukill stated that the shoe which had been under test by him for 35,000 miles contained about 0.70 per cent carbon, low chromium and a little nickel. The brake-drum liner is ordinarily mild steel having from 0.10 to 0.20 per cent carbon. Inasmuch as a second test showed a duration of only 5000 miles after the first had given 20,000, an investigation developed the fact that the mild steel used in the first test had been rolled from scrap armor-plate from a junked battleship.

Oil or water, added Mr. Hukill, has practically no effect unless the flow is continuous. Casual oil or water will be burned off by a single application of the brake. The weight of the airbrake equipment with an accumulator is between 50 and 60 lb., depending somewhat on the special levers and brackets required for connecting the linkage. The weight of the model shown by him, said Mr. Bragg, was not more than 22 lb.

When questioned as to the effect of moisture in the valve mechanism as regards freezing, Mr. Hukill asserted that some trouble had been experienced in early equipment that used an accumulator as a source of supply, for one of the products of combustion is water; another is an oily sludge. Freezing usually occurred in the line between the accumulator and the reservoir. Since using a compressor, no such difficulty has occurred.

With regard to the locations of the accumulator and the compressor, Mr. Hukill said that an accumulator is used only on passenger cars on which the equipment is installed after the car has been in service; when the airbrake equipment is installed at the factory as standard equipment, a compressor is recommended.

HOW ENGINES AFFECT OILS

While the effects of lubricating oils on engine operation have been much discussed, L. Wagner, superintendent of engineering of the Standard Oil Co., told members of the San Francisco group, at its meeting on the evening of March 26 at the Richelieu Hotel, how engine operation affects lubricating oils. His address gave the results of exhaustive research and experimentation on the vital problems of lubrication of the engines of automobiles, motorbuses, trucks and tractors. The members gathered for a group supper at 6:30 p. m., preceding the business session.

SUPERCHARGERS FOR AIRPLANES

Various Steps in Their Development Outlined at Meeting of Dayton Section

The development of superchargers for airplane use was outlined by E. T. Jones, chief of the powerplant section of the engineering division, Army Air Service, before the Dayton Section on March 11. In following the various steps of this development, Mr. Jones dealt particularly with the troubles that had been encountered and the means of correcting them to which recourse had been had. Slides illustrated many interesting details of construction and numerous typical installations of the supercharger on service airplanes.

It was pointed out that the greater part of the work done on superchargers by the Engineering Division has been with the exhaust-driven type developed by the General Electric Co., as this type appears to possess the greater advantage from both the mechanical and the thermodynamic points of view. Mr. Jones believes, however, that the direct-driven type will prove useful for intermediate altitudes, as this type can be made lighter and requires less modification of the structure of the airplane when the supercharger is installed.

An additional advantage of the gear-driven type was said to lie in its immediate response to control. The opinion was expressed that, for extremely high altitude work, the turbine-driven type will continue to prove more effective and that, for intermediate altitudes in the vicinity of 10,000 to 15,000 ft., a considerable field may exist for the gear-driven type.

Upon the conclusion of Mr. Jones' remarks, an animated cartoon was exhibited that had been prepared by the Engineering Division for the purpose of instructing Air Service pilots in the functions and methods of operation of the turbo-supercharger.

Use on Racing Automobiles

In response to questions, Mr. Jones stated that, in his opinion, superchargers would be used more and more on racing automobiles, since this type of service represents a special case in which the sole requirement is the maximum power-output at high speed from a limited piston-displacement. On the other hand, it was asserted that superchargers cannot be used to increase the torque throughout the speed range on passenger and commercial vehicles, because an increase in the induction-pressure by the supercharger would result in increased detonation unless the compression-ratio of the engine were reduced. This reduction would, of course, affect the fuel economy adversely. It was stated that this effect had not been thoroughly investigated by the Engineering Division; such data as are available, however, indicate that to increase the power output of an engine by 5 per cent, an increase of 10 per cent in the specific fuel-consumption would be required.

Advantage to Automotive Engines

Mr. Jones also believed that two possible advantages are to be derived from the application of superchargers to automotive engines: (*a*) the possibility of maintaining the maximum torque at much higher speeds by designing the supercharger so that the pressure rise will be appreciable only at the higher speeds and (*b*) an improvement in distribution caused by placing the carbureter on the suction side of a high-speed centrifugal supercharger, thus utilizing the temperature rise and the mechanical churning of the mixture to secure uniform distribution.

To a query whether the turbine-driven or the gear-driven type is the more suitable for automotive use, Mr. Jones replied that the turbine-driven type seems to possess the advantages of extreme mechanical simplicity and of great flexibility of control; whereas, the gear-driven type seems to be superior as regards compactness, and can probably be built as an integral part of the engine; the turbine-driven, he thought, would have to be developed as a separate unit.

THE INDUSTRY'S RECENT ACHIEVEMENTS

Present Phases of Automotive Activity Enumerated for the Chicago Section

Research work, recent progress and tendencies in automobile and in tractor design, as well as the subject of shock-absorbing devices, comprised the varied program of the meeting of the Chicago Section held on March 20 in Chicago. The speakers were H. L. Horning, president of the Society and president also of the Waukesha Motor Co., Waukesha, Wis.; J. S. Erskine, chief engineer of the gas-power laboratory of the International Harvester Corporation of America, Chicago, and W. B. Grooves, of the Stromberg Motor Devices Co., Chicago. Many phases of the automotive industry were considered by the speakers and some discussion followed, although it was brief because of limited time. Some of the important features of the proceedings are included in the following account.

Among the outstanding impressions received by President Horning while attending the recent automobile shows, he mentioned the great improvement in the design of engines with relation to improved combustion and said that the consistent serious effort on the part of the designers to obtain better engine performance was noticeable. Lubrication problems also have been given effective study, many lubricating devices and lubricant cleaners being in evidence. He considers it remarkable that engine cylinders have heretofore lasted so well, in view of the fact that oil dilution, the products of combustion, carbon, metal particles and other abrasives cause such serious wear unless they are eliminated. One device divides the stream of oil and filters a portion of it while the other portion is being used; in this manner, the oil does not have a chance to become contaminated. He believes devices for cleaning oil while it is in use will be widely adopted, and some system for putting clean oil on the bearing surfaces will be developed; also, that air-cleaners will be used extensively.

Speaking with regard to the riding-quality of cars, President Horning referred to the varied psychological factors that influence different personalities, either favorably or unfavorably, in addition to the effects produced by the machine itself. Vibration is a major cause of poor riding-quality, he said, and he believes the engine can be prevented from transmitting its vibration to the chassis; some of the exhibits evidenced improvements in engine mountings. The most suitable location of the accelerator pedal is also conducive to good riding-quality.

Features of style, finish, brakes, tires, number of engine cylinders and the like were observed and commented upon by President Horning, but these were too numerous for inclusion in this report.

Referring to research work and to the Research Department of the Society, President Horning expressed great satisfaction in the recent acquisition of the services of Otto M. Burkhardt as manager of this Department, and outlined briefly the speedy and effective research work the Department is competent to perform under his supervision. He recalled the work already accomplished as the result of research tests to determine the most economical fuel, and cited instances within his personal knowledge in which data desired by himself and by others had been furnished almost immediately by the Department. In conclusion, President Horning emphasized the desirability and importance of the Research Department's work, and urged that full use be made of its present facilities for obtaining and disseminating needed engineering data.

Tractor Design Progress

Mr. Erskine's paper dealt particularly with tractor development during the last year; it treated the subjects of general design, carburetion, ignition, air-cleaners and the possibilities of future development. As to design, he quoted a representative engineer as having said that companies formerly persistent in using open gears and plain bearings have brought out or are now bringing out designs having complete gear enclosure, and that anti-friction bearings have been substituted for those of the plain type. Also, Mr. Erskine said, an almost universal adoption of steel that has improved physical qualities for usage in shafts and gears has occurred, the heat treating of steels has become more widespread and so has the use of ball and of roller bearings.

Tractor carburetion has, for more than 15 years, been designed for the use of kerosene as fuel; it has proved a satisfactory fuel and very good performance can be obtained with it, in many cases comparing favorably with that given by automobile engines using present-day gasoline. Carbureter development for tractors has been along lines of uniform metering of the fuel without having any lean or rich spots over the entire range, of vaporizing the fuel to such an extent that it is suitable for use in the cylinders, and of distributing the mixture in such a manner that each cylinder will receive its correct portion of the charge. Mr. Erskine stated his belief that, for kerosene burning, for which a great amount of heat is required, the use of a hot stove affects the horsepower output so materially that it cannot be considered for this use, and that this condition has turned the attention of practically all designers of kerosene-burning engines to the hot-spot manifold.

The statement was made that no startling changes in ignition practice have developed, and that the use of the magneto is almost universal in the tractor industry. When suitable arrangements can be made, it is hoped that the entire magneto and magneto drive can be enclosed in a dust-proof box. The present development of air-cleaners is toward more effective cleaning, and toward requiring less attention on the part of the operator to keep the cleaner in operation.

Regarding future possibilities of tractor development, Mr. Erskine remarked that if the tractor can replace the horse for field work and do all the work for less cost, it will have a wonderful future; but, so long as it is necessary to keep and to feed a number of horses to do work that a tractor cannot do, and have the horses idle during the plowing season, it probably will be true that the gain by tractor usage on small farms will remain problematical.

Shock-Absorbers

Reviewing the history of shock-absorber development briefly, Mr. Grooves then mentioned many of the types of shock-absorber now on the market and remarked that practically all present a problem in that they provide greater friction in cold than in hot weather. It was thought formerly that, with the advent of the balloon tire, no need would exist for shock-absorbers, but such tires have been found to create a larger market for snubbing devices than was true previously. He believes the desirable shock-absorber to be one that will allow a certain amount of free action to the spring and then become active when the most severe throws or vibrations are produced. As to the "gallop" evidenced by balloon tires, he thinks a one-way snubbing-device affords the best means of eliminating it.

Springs for shock-absorbers were discussed by Mr. Grooves, who also considered the connecting link between the axle and the frame. He favors the steel cable rather than the cotton strap, because it is stronger and is affected less by dust and dirt. The main difficulty in using steel cable is to attach its upper and lower terminals securely.

AUTOMOTIVE RAILROAD CARS

Light railroad cars driven by internal-combustion engines, as used on steam railroad branch lines, was the subject of discussion at the monthly meeting of the Minneapolis Section held the evening of March 26 at the Manufacturers' Club in that city. The principal speakers of the evening were E. J. Brennan, superintendent of motive power of the Chicago Great Western Railroad Co., and E. R. Manor, assistant engineer of tests of the Northern Pacific Railway Co. Other railroad and automotive men of the Twin Cities participated in the discussion of the subject, which is of growing importance to railroad executives and to automotive engineers and manufacturers.

EDUCATION FOR LEADERSHIP IN INDUSTRY

ONE adviser suggested that an effort be made to formulate a satisfactory philosophy of economic effort; then develop the function of engineering in this philosophic scheme; next consider how engineering effort should be organized for its most effective service—all as a preliminary to worthwhile thinking about the way to educate young engineers!

Prudence has suggested working toward both the philosophical and practical ends from an intermediate starting-point. What is to come bears a logical relation to what has been and can be discovered in part in the experience of the colleges and of their graduates. Such evidence can be gathered from the 140 or more engineering colleges only by general cooperation.

The United States Bureau of Education should be one of the most important cooperating agencies in drawing upon the experience of the colleges. A survey is being made of requirements for admission and requirements for the bachelor's degree, or its equivalent, in engineering courses throughout the United States, under the direction of Dr. W. C. John. A study is also being conducted of the historical evolution of the content of engineering curricula and of the variety of curricula offered in a representative group of 15 institutions. The entire undertaking is a sympathetic study of engineering education by its friends and not a hostile inspection of engineering schools by their critics. The danger in such a study is not that we shall be too radical, but that we shall fall into the temptation of rationalizing the status quo, that is of piling up plausible reasons for going on as we have been.

It seems reasonable to anticipate a considerable increase in demands upon the colleges. As a measure of preparedness it may be important to make a survey of the capacity of the engineering colleges as now equipped, staffed and financed to supply men. The facilities of an engineering college are generally known to be of a relatively costly nature. The only continuing contact between the professional organizations and the schools has been through the student branches of the national engineering societies.

Theory and Technique of Education

A vast volume of experimentation, testing and discussion is going on in the realm of educational technique. Aside from certain inconclusive experiments with mental tests as related to admission problems, the results of which are as yet unpublished, the engineering colleges as a group have been largely untouched by this movement. To be true to his calling the engineer has to be both a tireless experimenter, one who tests all things, and a judicious standardizer, who holds fast to that which is good. In the realm of practice he has done both conspicuously, while in the realm of education his experimenting has been timid and his tendency toward standardization, as revealed by the widespread copying of conventional models, pronounced.

About half our problems seem to have their roots in the question of how to get and keep the right boys in engineering colleges. Can the colleges assume that their students have already been through a vocational sorting process or is the task one which the colleges themselves must assume? The selective process which brings the student to an engineering college operates at or near graduation from the secondary school. Can there be valid vocational guidance or educational sorting along vocational lines at this stage of maturity under present American conditions? On examination this appears to be a field where enthusiasts rush in, but where experts fear to tread.

The foundations of maturity, knowledge of self, knowledge of different fields of human effort and stabilization of interest needed for valid vocational differentiation do not exist among the vast majority of high-school graduates. Further opportunity for self-discovery and a broader outlook on life is needed before an educational program of definite vocational aims can be attempted with confidence. The early years in college are apt to remain a sorting ground for some time to come.

It is hoped that some start may soon be made toward determining the group of personal attributes which are most significant in predicting success in engineering study, and if possible, in predicting engineering achievement. If a half dozen really basic aptitudes could be identified and reduced to fairly trustworthy quantitative scales, with an objective technique of testing, it might be possible to determine from cases of known degrees of success the range of individual variation on such scales within which students could be classified as good risks for an engineering training. It would then be possible for a student who is contemplating an engineering course of study to submit himself to examination by a competent disinterested agency and be advised as to the odds favorable or adverse to his success. This is a problem of manifold difficulties, some of which are psychological and some incidental to lack of agreement as to where the limits of engineering shall be chosen. It seems imperative that at least a partial solution should be found, if any substantial progress is to be made toward a more rational plan of selecting students of engineering. There must be kept in mind the organic unity which is presumed to characterize an engineering curriculum, in contrast to the greater freedom of election in arts courses; also the scope for individual pace and excellence afforded by the great amount of project work in the engineering courses. The educational program of engineering is notably severe in its demands on time and energy.

The result of the wide availability of engineering education at low cost and its close articulation with public secondary education has been that in recent years we have given this form of higher education to a much larger proportion of our population than has ever been the case in any part of Europe, prewar Germany included. Many men so trained were of mediocre gifts, many men of all grades have not followed engineering in a narrowly professional sense, but all have been absorbed into our economic and public life and have richly leavened it with an attitude of expectant sympathy toward technological progress. No doubt this wide diffusion of engineering training has done much to uncover the latent deposits of engineering ability in American youth, carried over as an inheritance from the pioneer life of the Country.

Granting all that has been claimed for the formal superiority of European education, although it has probably been over-stated, it may still be true that American policies and standards have been vastly more advantageous to the economic development of the Nation than a close adherence to European models might have been. The engineering curricula under study are being analyzed to show the proportionate requirements of each year in four general groups, made up of 15 subgroups.

The great mass of American engineering students receive very little less than 2 years of work which would be entirely acceptable toward a degree in practically any college of arts and sciences. The members of pre-law and pre-medical students who voluntarily take more than 2 years of collegiate work are probably not greater than in engineering. The characteristic differences between the prevailing educational standards in law, medicine and engineering are seen to be in the realm of the length, definiteness and severity of the purely technical training rather than in the realm of the collegiate foundation work or cultural requirements, whatever they may be.

If a more extended technical training is needed by a considerable proportion of engineering graduates, and there are good reasons for thinking this to be so, may it not be necessary to seek elsewhere than in the precedents set in other and unrelated professional fields for an example? Perhaps no adequate example can be found and it may be

necessary to work out de novo a plan of supplementary specialized education for graduates who have had the experience needed to orient them to a definite field of activity and to enable them to discover equally definite educational needs.

The question "What distinguishes a profession from a business, a trade or any other form of vocation" is one for which an answer is being sought by the conference group representing the professional engineering societies and the colleges of engineering. The search for an adequate definition of a "profession" has revealed three characteristic varieties. One man says it is all an *attitude of mind*, that any man in any honorable calling can make his work professional by an altruistic motive. Another says it is a certain *type of work*, the practice of a science or art, which has come to be conventionally regarded as professional. A third says it is a special *order in society*, a group of persons set apart and specially recognized as charged with a distinctive social function, as the bar, the bench and the clergy. Some approach the matter from the viewpoint of the ideals which the professional group *profess*, while others think only of the acts they *practise*. All recognize that there are characteristic attributes of *individual* professional life and attributes of *group* professional life.

It is not intended to imply that professional men can be trained only in professional schools, but rather that an equivalent of serious study and reflection is requisite.—From a report by W. E. Wickenden, director of investigation, Society for the Promotion of Engineering Education.

SYNTHETIC LIQUID FUEL

THE manufacture of synthetic petroleum on a commercial scale has been much to the fore in France since the war. The object aimed at by the scientists and engineers who advocate its use is to render the country absolutely independent of outside supplies of liquid fuel and also to utilize to the fullest extent the natural resources, both actual and potential, of France and her colonies. Synthetic petroleums, as is well known, have been obtained in laboratory researches for many years past, starting from animal and vegetable fats, and from coal, shale, lignite, peat, and vegetable matter or refuse of various kinds.

Berthelot, about 75 years ago, succeeded in transforming into hydrocarbons over 100 different organic substances. M. Mailhe, professor at Toulouse University, in dealing with the extraction of synthetic petroleums from vegetable and animal oils explained how he obtained the synthetic products he aimed at by the catalytic decomposition of linseed oil. By treating under similar conditions rape-seed, olive, groundnuts, palm, copra, fish, whale and other oils, a very similar petroleum was obtained. Castor oil, besides hydrocarbons, yielded a certain quantity of oenanthole, an aldehyde utilizable directly or after transformation by hydrogenation. Slight differences noticed in the various synthetic petroleums obtained did not arise from the different nature of the oils treated, but more from variation in the temperatures of reaction, or from the greater or less activity of the catalytic agent, or, again, from the rapidity with which catalysis was effected. The method followed had been applied both to the raw oils and to those that had been refined. The actual cost of manufacture of synthetic petroleums being low, the cost of the products themselves depends mainly upon that of the oils to be treated. A prime necessity, therefore, is to provide for the rational cultivation on a large scale of the suitable seeds and nuts, to decrease the cost of vegetable oils much below the market prices now ruling. Professor Mailhe also alluded to the treatment of chlorophyl extracts for making synthetic petroleums; he said that these extracts could be obtained comparatively cheaply from numberless plants, without detriment to the other customary uses to which many of them are now put.—*Engineering* (London).

ARCADED STREETS PROPOSED FOR NEW YORK CITY

THE New York City of the future will be an adaptation of the metropolis to the needs of traffic, freeing the city from the unsightly congestion and turmoil of the present. Pedestrians will move about through arcaded streets, out of danger of traffic, protected from the snows of winter and the glare of the summer sun. Walking would become a pleasurable pastime, and cease to be one of the most hazardous of occupations.

Let us now take the first step in this contemplated change of levels, and build a raised sidewalk the length of the block on both sides. This can be constructed on piers built 1 or 2 ft. from the building line, and carrying a cantilever beam with the short end in the building wall for a shoulder. The old sidewalks become additional street space, the necessary room for loading and unloading vans and parking autos is provided and the portion of a narrow street left free for moving traffic is increased from 10 to at least 30 ft., an increase in capacity of 200 per cent.

When a block is rebuilt, the temporary cantilever sidewalk would be removed, the new arcaded sidewalk opened and the area under the sidewalks opened for loading or unloading vans or motor-vehicle parking. The street space available for moving traffic would be widened to 60 ft., an increase of 300 per cent more, making a total of 500 per cent. The process could continue until the entire surface under the buildings would be available for traffic, if ever conditions demanded it.—H. W. Corbett in *American City Magazine.*

SHRINKAGE OF RAILROAD PASSENGER-TRAFFIC

RAILWAY AGE calls attention to a fact of great importance in connection with the operation of the railroads of the United States, namely, that since 1920 the total passenger business of all the railroads of the Country has decreased approximately one-fourth, this shrinkage being principally attributable to the increased use of automobiles. The problems the railroads are called upon to solve by reason of this serious loss of traffic are numerous and difficult. One of these is that of the rates which the diminution of their income from the cause mentioned makes it necessary for the railroads to charge on all their traffic, freight as well as passenger. This, in fact, is one of the chief reasons why substantially the present freight and passenger rates are required to keep the carriers solvent.—*Economic World.*

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

RESEARCH, THE NATION'S GREATEST ASSET

Results of Research Indestructible—How Business Men Look Upon Scientific Work

The permanence, the endurance and the stability of an individual, as well as of a nation, are qualities directly dependent upon resources. An individual may fail but, with proper mental equipment, he will gradually readjust himself to the new condition and rise again. This also holds true for a nation.

We marvel and are awed by the grandeur of Niagara Falls. This inexhaustible and everlasting display of energy is possible only because of tremendous resources, which, in this case, are four great lakes. On the other hand, nations such as Greece and the Roman Empire would hardly be spoken of today if it were not for their intellectual achievements. These examples should suffice to convince even the lesser scientific and technical executives that research, being purely intellectual, is indestructible, and will help business enterprises as well as nations to survive not only the keenest competition but also wars and domestic disorders and, in addition, bring about closer international relations and, with them, trade expansion.

Attitude of Business Toward Sound Research

Some broad-minded executives of manufacturing organizations take serious and personal interest in the work and meetings of scientific societies. We must gratefully acknowledge the financial generosity that some successful business men display in assisting research work of a technical as well as a purely scientific nature. A striking paradox, however, is commonly found among American business men. It is characteristic of them to draw a sharp line of demarcation between business, on the one hand, and idealism, on the other. The main object of business, of course, is financial success; business leaders, therefore, in their attitude toward research, are inclined to limit it to such simple considerations and functions as will allow a direct and clear vision of increased profits. Notable exceptions are made by such establishments as the General Motors Corporation, General Electric Co., and others. The accomplishments of these organizations in research have not only proved profitable to their own institutions, but also to industry and to the Nation in general. This fact is also appreciated by our brothers and co-workers in Europe.

There are, however, scores of smaller business enterprises whose funds are insufficient for the maintenance of large laboratories and a large research staff. Furthermore, inasmuch as research work should be done either very carefully or not at all, and as good work requires elaborate equipment, it is obvious that smaller manufacturers usually confine themselves to the mere testing of their product.

On the other hand, at institutions of learning, laboraories are in existence that are wonderfully well equipped to carry on researches, the results of which could be profitably utilized by industrial organizations. The Society, through its Research Department, has kept and will continue to keep in close contact with work, carried on by scientific institutions all over the world, that is related and may be useful to the automotive industry.

Ordinarily, however, reports from universities and research committees are elaborate and, commonly, are conspicuous because of their profuse derivation and application of mathematical formulas. It is natural that all such treatises should appear impractical to the majority of designing and experimental engineers. These men usually consider such work as frightful. Upon major consideration, however, these formulas prove to be not only entirely conceivable and comprehensible but very useful to engineers. Many of them have now become the standards for designers and experimenters.

For purposes of illustration, let us take some of the treatises by Hertz. They are elaborate and purely mathematical but, in spite of this fact, are certainly indispensable. They are recognized as guiding principles by designers of ball and roller bearings and prove most useful whenever it is desirable to determine the stresses of elastic bodies at their contact areas.

To represent, in a form that may easily be assimilated by all engineers, such work as would otherwise be overlooked as too complex and theoretical, will be one of the functions of the Research Department of the Society. Such a step, it is thought, will bring about greater appreciation of the use of applied science and will finally prove the value of systematic designing. It will help to show how costly the use of the hit-and-miss method may be and, what is worse, the contemptible practice of copying faulty designs.

To illustrate still more specifically our intentions in this respect, we will choose a most valuable treatise of very recent date, namely, an investigation of the balancing of automobile engines, contributed to the British Institution of Automobile Engineers by H. S. Rowell.[1] We find in the Appendix 3 a very interesting analysis of connecting-rod inertia. It is stated:

> The important result for the six-cylinder engine lies in Equation (14) which, when transformed with Equation (16) gives the total moment of inertia forces for the six connecting-rods as
>
> $$2\,(n^2 - 1)\,(k^2 - ab)\sin 3\Theta/(n^2 - 4)^{3/2}$$

Application to Connecting-Rod Design

A connecting-rod of a high-grade six-cylinder engine was taken and the following numerical values were found:

$$ab = 0.165 \text{ sq. ft.}$$
$$k^2 = 0.130 \text{ sq. ft.}$$
$$n = 10.5/2.5 = 4.2$$
$$n^2 = 17.63$$

Substituting in the above equation, we find a moment of inertia for $\Theta = 90$ deg.; hence, $\sin 3\,\Theta$ deg. $= -1$ of:

$$I = [2(17.63 - 1)(0.130 - 0.165)(-1)]/(17.63 - 4)^{3/2}$$
$$= 1.165/50.3$$
$$= 0.0232$$

Inasmuch as the kinetic energy of a rotating body is determined by $K = I\omega^2 m^2$ and as the weight is assumed to be 2.5 lb., we obtain for an engine speed of 3000 r.p.m., after substitution, a value of $K = [2.5/(2 \times 32.16)] \times [0.0232\,(2\pi \times 3000)^2/60^2] = 89$ ft-lb. This value is nearly one-half the maximum torque of the engine and seems of incredible magnitude. If we consider that the whole value would be zero, if $k^2 - ab$ were zero instead of -0.035, there would seem to be a possibility of eliminating a considerable number of forces by a slight change in the connecting-rod design, if the paper is interpreted correctly. It seems, however, that Mr. Rowell's paper is not correctly understood. In cases such as this, the Society will make an effort to interpret apparent paradoxes and will help to make available useful treatises that otherwise might be laid aside in despair.

[1] See the *Proceedings of the Institution of Automobile Engineers*, vol. 18, part 2, p. 502.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

PAN-AMERICAN STANDARDIZATION

Kirke K. Hoagg, Representative of the Society, Outlines Action Taken at Lima

In June, 1924, a conference to which the Society was invited to send representatives was held in Boston at the request of the Inter-American High Commission to provide an opportunity for the technical industries of the United States to formulate a policy in the matter of a Pan-American Standardization Conference. Although the Society was not represented at the Boston conference, it was at subsequent meetings that were held to perfect plans for participating in the Pan-American Standardization Conference that was afterwards held at Lima, Peru, last December and January. In October an official invitation was received from Director General L. S. Rowe of the Pan-American Union to send a representative to the Conference at Lima. The officers and Council of the Society decided to accept the invitation after considering the nature of the Conference and what could probably be accomplished at it. It was understood that no definite standardization would be attempted as the purpose of the Conference was primarily to establish closer relations with the Pan-American Republics and arrive at an understanding as to how a standardization program could best be established by the several Republics.

Kirke K. Hoagg, a member of the Society, who is particularly well qualified to represent the Society's interests at such a conference, was selected to act as the Society's delegate to the Conference. The matter of financing Mr. Hoagg's trip was taken up with more than 50 companies which have been active in the Society's work and acknowledgment is made of the support the following companies gave to the project:

Firestone Tire & Rubber Co.
Ford Motor Co.
General Motors Export Corporation.
International Harvester Co.
Peerless Motor Car Co.
S.K.F. Industries, Inc.
Studebaker Corporation of America.
United States Rubber Co.
Waukesha Motor Co.

Mr. Hoagg sailed from New York on Dec. 6, accompanied by several other delegates to the Conference. The sessions of the Conference at Lima were held from Dec. 23, 1924, to Jan. 7, 1925. After Mr. Hoagg's return on Jan. 24 he submitted the following report of the Conference.

Report by Kirke K. Hoagg

Regular sessions of the Conference were held in the Engineering Societies Building at Lima and were well attended. While the number of delegates was not large, the majority were present at all sessions.

The official languages as designated in advance were Spanish, French, Portuguese and English, but Spanish was used throughout the sessions. It was necessary to arrange for translation of papers given in English into Spanish but there was some difficulty in doing this due to lack of facilities and a shortage of stenographers and translators. It should be borne in mind for future Conferences that adequate facilities should be provided for translating papers.

The first session for the transaction of official business was devoted to preparing a program for the presentation of the papers submitted to the Conference. These were too numerous and lengthy for presentation within the time allotted and arrangements were therefore made with qualified technical men to deliver verbal abstracts in Spanish of the papers written in English. Discussion of the papers was rather limited owing to their number, the majority of which were submitted from the United States.

The accomplishments of the Conference are embodied in the so-called Final Acts, which is a summary given for emphasis in Latin American Conferences, as it represents what is agreed to after considerable discussion. The Final Act should be read bearing in mind that the incorporated material was censored by a committee of five whose members were selected for their breadth of vision and conservative point of view.

A review of the Final Act in detail leads to the following conclusions:

(1) Adequate qualified channels or machinery are provided for carrying forward Pan-American Standardization through the Inter-American High Commission which is an established body

(2) Progress has been made toward bridging the natural language barrier to more complete commercial cooperation, this being indicated by provision for a glossary of standard terms in the several languages

(3) The Section dealing with weights and measures may be viewed as holding possibilities for controversy rather than harmony but it was inevitable that this topic should have come up. It appeared to your representative that this resolution of the Conference should be considered in two lights: first, as a matter of gratification that it has been placed where it will be subject to careful investigation during the next 2 or 3 years and, second, that it may be interpreted as a hint toward commercial advantage. The second conclusion is predicated on the fact that Latin Americans very evidently favor the metric system although they are buying considerable material from this Country that is made to the English measurements. This may be due primarily to existing economics but, assuming that European economic conditions improve to bring about even price competition, it is a question which goods the South Americans, given their choice, will take. I believe this represents in outline the reasons why the delegates from the United States considered it unwise to jeopardize the prevailing spirit of cooperation by opposing an introduction of this question too strongly. In the informal gatherings and talks among members of the official and unofficial delegations, it was clear that resolutions favoring an arbitrary insistence upon goods being manufactured to the metric system would be decidedly unwise. The portion of the Final Act calling for the next Congress to be held in the United States will make it possible to demonstrate this most clearly to delegates from the Latin American countries.

It may be that items of decided interest to the automotive industry such as "The English System of Measurement versus the Metric System" could be presented by individual manufacturers expressing their views to the Society. The Society could then present a summary of opinion to the United States Department of Commerce inasmuch as the recent Pan-American Standardization Conference and those to be held in the future are constituted of Government delegates who are the only ones having authority to instigate official action or commit their respective Governments.

THE OFFICIAL DELEGATES

Brazil—Manuel Cicero Peregrino Da Silva[1]
Costa Rica—Lic. Luis Anderson and Francisco Ballen[1]
Cuba—Fernando Sanchez Fuentes[1] and Ecay y Rojas
Guatemala—Ingo. Dn. Alejandro N. Puente[1] and Jose Ortiz de Zevallos
Haiti—Dr. Horace Etheart[1]
Mexico—Lic. Leopoldo Ortiz[1]
Nicaragua—Dr. Dn. Vazquez de Velasco[1]
Panama—Leopoldo Arosemena[1]
Paraguay—Eladio Velazquez[1]
Peru—Oscar F. Arrus, Gustavo Berckemeyer, Jose J. Bravo, Gerardo Klinge, Luis E. Olazabal and Heraclides Perez[2]
United States of America—Maurice H. Bletz, Dr. G. A. Sherwell and Albert W. Whitney
Uruguay—Rafael J. Fosalba[1]
Venezuela—Jesus Maria Herrera Mendoza[1]

DELEGATIONS OF THE INSTITUTIONS OF PERU

DELEGATES FROM PERUVIAN CHAMBERS OF COMMERCE

Lima—Santiago Acuna, Francisco L. Ballen and Luis G. Miranda
Piura—Alberto Delboy and Miguel Checa Equiguren
Cuzco—Armando de Lazarte y Tejada
Loreto—Dn. Julio C. Arana and Benjamin Duble
Huancayo—Dr. D. Oscar O. Chavez and Ingo. Gerardo Klinge
Junin—Antonio Vieshevich and Victor Priano
Pacasmayo—Charles A. Olivares and Jose M. Plaza
Chincha—Cesar A. Colonia
Callac—Jose E. Thornberry and Gustavo Berckemeyer
General Superintendent of Customs—D. Alfonso J. Saavedra de la Barrera and Dn. Carles Abrillide Vivero
National Agricultural Society—Guillermo Salinas Cossio and Jose Antonio de Lavallie
National Society of Industries—Reginaldo Asthon
School of Engineers—Enrique Laroza Edmundo N. de Habich and Juvenal Monge
Society of Engineers—Enrique Laroza Carlos Basadre and Ingo. Gerardo Klinge

UNOFFICIAL DELEGATES FROM UNITED STATES

American Society of Mechanical Engineers—J. H. Cerecedo
Carded Woolen Manufacturers Association—Samuel A. Dale
National Committee of Commercial Engineers of the Bureau of Education—Dr. Glen Lewis Swiggett
Society of Automotive Engineers—Kirke K. Hoagg

PAPERS PRESENTED

Address of Welcome—Dr. Heraclides Perez, director of public works of Peru, and active president of the Conference
Statement of Preparations for Conference—D. Jose J. Bravo, secretary of the Conference
Reply to Address of Welcome—Sanchez Fuentes (Cuba)
Message from Herbert Hoover, chairman, central executive council of the Inter-American High Commission
Introduction to the Study of Standardization—Dr. G. A. Sherwell, secretary-general, Inter-American High Commission
Address Officially Opening the Conference—D. Alberto Salomon, minister of foreign affairs of Peru
The Practical Problem of Organizing Pan-American Standardization—Warren E. Emley, American Society for Testing Materials
Cooperative Effort in Industry—W. Leonard Thompson, Department of Commerce
The Service Rendered by Standardization—M. H. Bletz, Department of Commerce
The National Bureau of Standards—George K. Burgess, director of the Bureau of Standards
The United States Government as a Purchaser—George K. Burgess, director of the Bureau of Standards
Standardization from the Standpoint of the Purchasing Agent—W. L. Chandler, secretary, National Association of Purchasing Agents
Standard Specifications and Methods of Test for Materials—C. L. Warwick, secretary-treasurer, American Society for Testing Materials
International Standardization—P. G. Agnew, secretary, American Engineering Standards Committee
Dimensional Standardization—E. C. Peck, American Society of Mechanical Engineers
The Story of Standardization in the American Automobile Industry—Coker F. Clarkson, general manager, Society of Automotive Engineers, Inc.
Standardization on Railways in North America—F. Lavis, consulting engineer, New York City
The Engineering Standardization Movement in Canada—R. J. Durley, secretary, Canadian Engineering Standards Association
Work of the United States Department of Agriculture in Standardization of Agricultural Products—Lloyd S. Tenny, Department of Agriculture
Wool Standardization in the United States—George T. Willingmyre, Department of Agriculture
The Standardization of Leaf Tobacco—Joseph Mendelsohn, National Cigar Leaf Tobacco Association
Standardization of Descriptions of American Grown Cotton—R. C. Dickerson, secretary and vice-president, American Cotton Shippers Association
Standards for American Milled Rice—Their Origin, Practical Application, Present Status and Effect on Business—F. B. Wise, secretary and treasurer, Rice Millers' Association
Standardization of Crop and Livestock Reports—William F. Callander, Department of Agriculture
The Commercial Apple Industry of the United States—Its Development, Specialization and Standardization—R. G. Phillips, secretary, International Apple Shippers' Association
The International Electrotechnical Commission—G. Semenza, president of the Commission.
The Principles of Standardization and Their Application to the Needs of the American States—Albert W. Whitney, associate general manager and actuary, National Bureau of Casualty & Surety Underwriters
Studies Presented by the Inter-American High Commission Concerning the Program of the Conference—Luis Arago (Mexico)
Memoranda Concerning the Identification of the Raw Products of Tropical America and the Organization of Museums—Herrera Mendoza (Venezuela)
Qualities and Specifications of Cottonseed Oil—Officer of Union de Fabricantes del Peru, Ltda.
Memorandum Concerning Standardization of X-Ray Equipment—J. H. Cerecedo (United States of America)
Memorandum Concerning Rubber-Producing Trees in

[1] Vice-Presidents of the Conference.
[2] President of the Conference.

the Region of the Amazonian Forests—Officer of the Chamber of Commerce of Loreto, Peru

Agricultural Paper on Sugar and Cotton from Sociedad Nacional Agraria del Peru

Memoranda from the Minister of Foreign Affairs of San Salvador

Monograph Concerning Lumber Specifications—Augusto Manrer y Cia (Peru)

Memoranda Concerning Exportation of Wool—C. Perez Albela (Peru)

Agricultural Standardization—Julio Riquelmo Indi (Mexico)

The Activities of the British Engineering Standards Association—C. le Maistre, secretary of the Association

The Belgian Standards Association—M. Gustave L. Gerrard, secretary of the Association

The Method of Promoting Industrial Safety by a Government Research Bureau—O. P. Hood, Bureau of Mines

The Standardization of Wool—Edward Moir, president, Carded Woolen Manufacturers Association

Standardization in America—Samuel S. Dale (United States of America)

Memorandum Concerning Standardization in Hide Production—Edward A. Brand, secretary, Tanners Council of America

Final Act of the Pan-American Conference

The First Pan-American Conference on the Uniformity of Specifications, meeting in Lima with duly accredited representatives from Brazil, Costa Rica, Cuba, Haiti, Guatemala, Mexico, Nicaragua, Panama, Paraguay, Peru, United States of America, Uruguay and Venezuela in plenary session on Jan. 3, 1925, approved the following resolutions:

FIRST RESOLUTION

Resolved—That it be recommended that the American States enter into a convention containing the following essential points:

(1) An agreement to provide for the continuous study and encouragement of the establishment of common standards and nomenclatures, uniform grades, simplified classifications and standard specifications for raw and manufactured materials

(2) To carry out this agreement the signatory countries shall oblige themselves to establish in their respective jurisdictions one or more organizations which may be either under governmental or private control or under the combined control of governmental and private interests as may be most suitable to each of the signatory states

(3) The organization or organizations established in each country will act as national centers for study and investigation concerning matters included in the scope of the subject, will provide for methods of test, shall be custodians of accepted standards and shall serve as a medium or maintain a close contact with the national organization which is the medium of international exchange of ideas and experiences in this field

(4) That such organizations, be they governmental or private, or both, shall be obliged to conform to certain regulations and restrictions:

(*a*) The maintenance of an adequate personnel

(*b*) Measures to obtain the proper cooperation and consultation from representatives of all interests and enterprises in their respective countries in the establishment of national standards

(*c*) The obligation to publish or have published the findings they make, the results obtained and any other information which may be of general interest

(5) To maintain inter-American communication and secure the establishment of inter-American standards, the Inter-American High Commission through the national sections of each country and the central executive council, is charged with the receiving and distributing of the work done in each country; the Commission will direct or effect such studies as it considers advisable, make proposals and take all necessary steps within its sphere of action to promote the establishment of inter-American standards

(6) The signatory countries shall oblige themselves to increase the technical and clerical staff of the Inter-American High Commission in their respective national sections, if that be necessary, in order that the work may be carried on without handicap

SECOND RESOLUTION

Resolved—That it be recommended that the Inter-American High Commission formulate and draft the convention referred to in the foregoing paragraphs, compiling it in such form as may be most adequate to accomplish with celerity the purpose of these resolutions.

THIRD RESOLUTION

Resolved—That while the above-mentioned convention is in the process of drafting and awaiting signature by the America states it is recommended that the Inter-American High Commission endeavor to obtain the passing of measures in each country which are consistent with this convention.

FOURTH RESOLUTION

Resolved—That it be recommended that the Inter-American High Commission undertake the gradual compilation of a glossary or list of standard scientific terms in Spanish, Portuguese and English (and French) and that all countries take proper steps to cooperate in this work.

FIFTH RESOLUTION

Resolved—That in the matter of uniform weights and measures, it be recommended that

(1) The topic be submitted to a committee for study and report at the next conference. The Inter-American High Commission is charged with the selection of this committee on which all countries shall be represented

(2) The units of weights and measures used in the different countries tend to the metrical decimal system and that in new specifications and in reforms made in specifications already existing, the unit of measure be expressed in the C.G.S. units, (centimeter, gramma, secundo)

(3) In catalogs and in commercial, industrial and technical literature published using weights and measures expressed in other systems, so far as possible, such weights and measures shall be accompanied with their equivalents in the metric decimal system

SIXTH RESOLUTION

Resolved—That it be recommended that the American countries hold the second Pan-American Confer-

ence on Uniformity of Specifications within 3 years in the United States at a place and date to be designated by the Inter-American High Commission.

SEVENTH RESOLUTION

Resolved—That the recommendations made by this Conference and the reports and recommendations which form the Appendix shall be communicated to the central executive council of the Inter-American High Commission so that it may procure their adoption in the countries of the Americas. A copy of the papers and reports presented to the conference shall also be sent to the Council so that it may analyze them for such proposals that it will be necessary to make to the American countries. Pending the publication of the proceedings of the first Pan-American Conference on the Uniformity of Specifications, the Council is empowered to publish the aforesaid reports in whole, in part, or in abstract.

EIGHTH RESOLUTION

Resolved—That these resolutions shall be communicated to all the governments of the Americas with the request that they be given support and approval. They shall also be communicated to the national sections of the Inter-American High Commission, to the central executive council of the Inter-American High Commission and to the Pan-American Union for such action as they deem necessary.

APPENDIX

In accordance with a resolution of the Conference there were incorporated in the conclusions the individual motions presented by the delegates, and approved by the Conference, as follows:

Motion Presented by Peregrino Da Silva

As industrial products and articles of commerce are, so far as concerns the registration of industrial and commercial marks, classified differently in each country; as marks registered in a given country may, in accordance with conventions or treaties be submitted for registration in other countries; and as from this diversity of classification difficulties arise which impede registration of marks, on account of the uncertainties which may arise in practice; the First Pan-American Conference on Uniformity of Specifications resolves

> To recommend the establishment in the countries of America of a uniform and detailed classification of industrial products and articles of commerce, such classification to be adopted in all bureaus charged with the registration of industrial and commercial marks.

Motion of Oscar O. Chavez

I, as a delegate of the Chamber of Commerce of Huancayo, being mindful of the practical importance of uniformity of weights and measures, the principal specifications in all trade, to commerce in general and to the public in particular, move that

> The Conference on Uniformity of Specifications intrust and recommend to the Inter-American High Commission the unification of weights and measures.

Motion of Dr. Eladio Velasquez

The First Pan-American Conference on Unification of Specifications, as a means of promoting the uniformity of classifications of exportable agricultural products resolves

> To suggest to the American government the advisability of establishing, by degrees and legally, in each country, an agency controlling the classification of exportable agricultural products, this function being performed either by suitable private institutions, such as Exchanges or Chambers of Commerce, or being officially performed by definite administrative bodies.

As the necessary complement of the carrying out of the foregoing proposal it is recommended that each country advise other countries exporting similar products of its classifications, giving the exact terms employed for each group.

Motion of J. H. Cerecedo

Let the First Pan-American Conference on Uniformity of Specifications recommend to scientific societies, polytechnic institutes, universities and Pan-American institutions interested in the important work of standardization and connected with the physical, medical and industrial use of the application of X-rays, Roentgen rays in their various phases, the standardization in Pan-American countries of electrical terms of measurement, for the purpose of indicating with practical names, universally known, the intensity, current, and difference of potential, voltage or penetration, to which a cruet of X-rays is subjected for various purposes during the charge.

The electrical terms recommended are:

> For unit of intensity—the milliampere
> For unit of difference of potential—the kilovolt, measured by standardized sphereographs

Motion of Dr. G. A. Sherwell and Peregrino Da Silva

As standardization of specifications must include standardization of weights and measures and standardization of money as a measure of values; as standardization of weight and measures has been the purpose of a motion presented in the section on Dec. 27, 1924, to the effect that the metric decimal system, whose superiority is unquestionable, be recommended for adoption; and as the establishment of a single monetary unit or units having definite relations to each other, uniformly divided, would be of inestimable advantage to the countries of this continent; the First Pan-American Conference on the Uniformity of Specifications meeting in Lima resolves

> To suggest to the governments of America the advisability that preferential study be given to the problem of the money to be adopted as a common monetary unit, or units having a fixed relation to each other, uniformly divided.

Motion of Ingo. Ricardo Duestrua

As in the majority of American countries there are rich and extensive deposits of petroleum, closely connected by a common interest consequent upon the increasing world demand for light distillates derived from crude oils and by the marked impoverishment experienced in the principal sources of production, it becomes necessary to establish a common unit of measurement for the best valuation of the deposits above mentioned, of the work which can be done with them, and of the products that they can yield; and as such unit of measurement should be based upon the metric system which is that most common in the majority of American countries; the First Pan-American Conference on the Uniformity of Specifications recommends

(1) For the measurement of surface area of petroleum deposits—the hecter
(2) For lineal measurements—the meter
(3) For the measurement of crude petroleum and the combustible residuum of its distillation—the cubic meter
(4) For the measurement of gasoline, benzine, illuminating oils, gas producing oils, and for light and heavy lubricants—the liter
(5) For the measurement of lubricating greases, paraffine, and other solid derivatives of distillation of crude petroleum—the kilo of 1000 grams
(6) For the measurement of natural gas—the cubic meter

JOINT MOTORCOACH MEETING

Starting Motors and Generators Discussed—Coach Specifications Recommended

The Motorcoach Division of the Society's Standards Committee met with the Automotive Electric Association in Cleveland on March 2 to discuss the standardization of starting motors and generators for motorcoach installations. It was felt that such standardization of equipment on motorcoaches, similar to the classification of starting-motor and generator sizes and capacities for automobiles that has already been adopted by the Automotive Electric Association, will benefit both the motorcoach and electrical equipment manufacturers by facilitating the designing of the equipment and its installation and adequate operation on motorcoaches, and will tend toward reducing its original cost.

The capacities of generators required for service on the various types of motorcoaches was discussed at some length and the feeling prevailed that the rapid developments in motorcoach design will necessitate careful study in order to make this project acceptable. It was finally agreed that a subcommittee of the Automotive Electric Association would be appointed to report tentative recommendations based on the following generator capacities and speeds:

Capacity Watts	Speed for Maximum Output, R.P.M.
250	1000
400	1200
600	1400

The values given in the table are based on a generator speed of 1½ times that of the engine, but further study of this problem may indicate that some other ratio should be used because motorcoach engines usually operate differently from passenger-car or even motor-truck engines, so far as range of operating speeds is concerned. The Society and the Automotive Electric Association cooperate closely in all such work and the results of the investigation by the subcommittee mentioned above will be available to the Motorcoach Division and members of the Society through THE JOURNAL.

Following the joint meeting a regular meeting of the Division was held to consider its own schedule of subjects. The first subject considered was that of nomenclature for various types of motorcoaches. At a joint meeting of the S.A.E. Motorcoach Committee and the American Electric Railway Association Subcommittee in Pittsburgh, March, 1924, a tentative nomenclature was recommended which divided motorcoaches into two general classifications, city type and intercity type. The former was sub-classified as single-deck or double-deck and the intercity type was subclassified as sedan, aisle or chair. It was felt later that the aisle and chair classifications have become practically the same through recent developments in design and it was therefore decided at the Division meeting to combine them under the terms "parlor." The Division then voted to recommend that the following nomenclature for motorcoaches be adopted as S.A.E. Recommended Practice:

MOTORCOACH NOMENCLATURE

City Type

(1) Single-Deck having cross or longitudinal seats

(2) Double-Deck having cross or longitudinal seats

Intercity Type

(1) Sedan having multiple side doors and full cross seats

(2) Parlor having front and emergency doors and fixed or movable seats separated by an aisle.

The desirability of formulating detailed standards distinctively for motorcoaches was discussed but it was decided not to undertake such a program at this time because the motorcoach manufacturers felt that this type of vehicle is still in too much of a state of development and such detailed standards, if adopted now, would be disregarded or prove to be more or less of a handicap to manufacturers who attempted to adhere to them.

In the January, 1925, issue of THE JOURNAL, part of the discussion at the final public hearing by the New Jersey Board of Public Utility Commissioners on the proposed New Jersey regulations for motorcoaches was printed, together with the regulations as subsequently adopted by the Board and the recommendations that the S.A.E. Motorcoach Committee had made to the Board. The Division, at its meeting on March 2, discussed whether, as a matter of policy, the Society should make any definite recommendations with regard to motorcoaches along the lines of the specifications adopted by the State of New Jersey, or whether the Division should seek to establish contact with the officials in different States if and when they might draft similar regulations. It was suggested that the Division might leave all such matters to other organizations, such as the National Automobile Chamber of Commerce as representing the manufacturers and the American Electric Railway Association as representing a large class of operators, but it was the opinion that the Division should cooperate directly in such matters.

The Motorcoach Committee's previous recommendations for the single-deck city-type of motorcoaches were reviewed, with the idea of establishing definite broad recommendations by the Society to serve as a guide to motorcoach manufacturers and to the officials of States other than New Jersey in the preparation of similar State regulations governing this type of vehicle. The Division agreed that it would be unwise to have such recommendations more restrictive than is necessary to insure the development of motorcoach design along proper lines, particularly with regard to general constructional practices that affect the safety of motorcoach operation and motorcoach passengers. It was finally voted to tentatively recommend for adoption as S.A.E. Recommended Practice the following introduction and general specifications for the single-deck city-type of motorcoaches:

MOTORCOACH SPECIFICATIONS FOR GENERAL CONSTRUCTION AND EQUIPMENT SINGLE-DECK CITY-TYPE

In November, 1923, a small committee representing the Society was appointed to cooperate with the Equipment Committee of the American Electric Railway Association in making a study of the development of motorcoach designs with especial regard to the possibility of developing and promulgating motorcoach standards. Soon thereafter the transportation department of the New Jersey Board of Public Utility Commissioners and representatives of several of the larger municipalities in New Jersey drafted a number of regulatory specifications to govern motorcoach design and equipment for enforcement in New Jersey. Arrangements were made whereby the Society and American Electric Railway Association committees cooperated with the New Jersey Board in this work. It was understood at that time that the proposed regulations were to apply to the single-deck city-type of motorcoach, and in November, 1924, the Society's Committee submitted recommendations accordingly to the New Jersey Board. However, after the final public hearing held by the Board at Trenton, N. J., on Nov. 25, it was ruled that the regulations would apply to all motorcoaches coming within the jurisdiction of the Board of Public Utility Commissioners in New Jersey. On Dec. 29, 1924, the final regulations, which include a number of the Society Committee's recommendations, were issued to apply to all motorcoaches placed in operation thereafter in New Jersey.

At the beginning of the 1925 administrative year of the Society, the Motorcoach Committee was reorganized into the Motorcoach Division of the Standards Committee. Inasmuch as New Jersey is one of the first States to adopt motorcoach regulations, the Division believes that a series of recommended general specifications that have been approved by the Society will serve as an effective guide to officials of other States in formulating regulations that will be sufficiently uniform in their requirements to place no serious handicaps on motorcoach manufacturers or operators, or restrict suitable development of this type of vehicle.

The following specifications are therefore tentatively recommended by the Division for approval and adoption by the Society as applying to the single-deck, city-type of motorcoaches, see S.A.E. Recommended Practice for Motorcoach Nomenclature. They are necessarily broad in scope and should be considered only as a guide to desired uniformity of motorcoach design and equipment.

Width of Door.—The entrance and exit door of motorcoaches shall have a minimum clear width of 24 in.

Emergency Door.—Motorcoaches shall be provided with an emergency door located at the rear of the left side or in the center of the back. The door shall have a minimum clear width of 18 in. and extend from the floor to the upper belt-panel

Panel.—The construction of the front end of motorcoach bodies shall be such as to afford the driver an unobstructed vision to the right and left. The construction of the window at the left of the driver shall be such that it may be readily opened for hand-signaling purposes

Handles.—Rails or grab-handles must be located inside the vestibule and shall be securely fastened

Ventilators.—Motorcoaches shall be equipped with ventilators of a suitable type to assure proper ventilation

Heating.—An adequate heating system shall be installed when required

Gasoline Tanks.—When the gasoline tank is installed inside of the body, it shall be filled and vented from the outside of the body and shall be completely enclosed inside the body to separate it from the passenger space

Mirrors.—All motorcoaches shall be provided with an inside mirror

Footboards.—The front footboards shall be constructed of fireproof material

Fire Extinguisher.—All motorcoaches shall be equipped with at least one fire extinguisher, which shall be maintained in proper condition and exposed to view at all times

Inside Lights.—The interior lighting shall be at least 5 rated cp. per seat passenger capacity

Wiring.—The minimum size of wire from the battery and the generator to the point of lighting distribution shall be No. 8 A.w.g. stranded. For the interior distribution system of lighting, two lamp circuits in parallel are recommended, for which the minimum size of wire shall be No. 12 A.w.g. stranded, or the equivalent. When more than two lamp circuits are used, the minimum wire-size shall be No. 14 A.w.g. stranded, or the equivalent. All terminal connections shall be soldered and all splices shall be soldered and taped

Passenger Signal System.—Suitable signaling devices shall be installed within easy reach of all passengers

Stop-Lights.—All motorcoaches shall be equipped with a stop-light

Destination and Route Signs.—A route sign shall be located over the windshield on all motorcoaches and so placed and illuminated that it may be read day or night from at least 70 ft. ahead of the vehicle. It must not interfere with the driver's vision or produce an annoying glare

Overhang of Body.—The maximum rear overhang of the motorcoach body beyond the center-line of the rear-axle shall be 7/24 of the overall length of the chassis

Height of Chassis Frame.—The maximum height of the frame, measured from the ground level to the top of the frame, without payload, shall be 35 in.

Brakes.—Motorcoaches equipped with only one set of wheel brakes shall have two distinct methods of operating them

Wheel-Housing.—The construction of rear wheel-housings shall be such that no damage can result from bursting tires. The construction of the fenders shall be such that no undue accumulation of dirt or foreign matter can be deposited on the body

Exhaust.—The arrangement of the exhaust piping shall be such that the passengers will be adequately protected from the exhaust gases.

To Review Standards and Recommended Practices

Inasmuch as the Motorcoach Division is a new one, having been established at the beginning of this administrative year of the Society, the Standards and Recommended Practices already adopted by the Society and published in the S.A.E. HANDBOOK were scheduled for review with the purpose of designating those that are adaptable to motorcoach construction. As this work is completed by the Division, the Standards and Recommended Practices so approved will be thus indicated in the S.A.E. HANDBOOK.

The Society's Motorcoach Committee last year cooperated closely with the Equipment Committee of the American Electric Railway Association and the plans of the Division for this year's work include the continuation of this close contact. Those present at the meeting of the Division were:

G. A. Green, Yellow Coach Mfg. Co., *Chairman*
R. S. Burnett, Standards Manager, Society of Automotive Engineers, Inc.
Charles Froesch, International Motor Co.
G. E. A. Hallett, General Motors Research Corporation
William T. Lutey, Lang Body Co.
R. E. Plimpton, *Bus Transportation*
A. J. Scaife, White Motor Co.
P. V. C. See, Northern Ohio Traction & Light Co.

NEW SCREW-THREAD DESIGNATIONS

In view of the recent Society approval of the report of the Screw-Threads Division on Screw-Thread Fits, the method of designating screw-threads and fits, which is recommended in the American Standard for Screw-Threads and which will be used in the future in the S. A. E. HANDBOOK, should be adopted in general shop practice in order that those in the industry may "speak the same language."

The basis of the system of identification is the initial letter of the thread series followed by the number of the class of fit. The thread series are designated as

F—Fine Series (S. A. E. Regular)
C—Coarse Series (U. S. Standard)

The fit classifications recommended in the American Standard and reprinted in the S. A. E. HANDBOOK are designated as

Loose Fit—Class 1
Free Fit—Class 2
Medium Fit—Class 3

Thus a threaded part of 1-in. diameter with 14 threads per inch and with the Free (or Class 2) fit would be indicated as

1"-14-NF-2

ard because it is used in the report of the National Screw Thread Commission and it is desired to have all practice in the Country uniform. If the thread is left-hand, the symbol LH follows the number of threads. No symbol is used to designate right-hand threads. If the above example were intended for designating a left-hand thread, it would therefore be indicated as

1"-14-LH-NF-2

The fit classifications applicable to automotive work are printed in the S. A. E. HANDBOOK beginning on p. C1. The complete American Standard for Screw-Threads can be also obtained in pamphlet form. The specifications issued by the National Screw Thread Commission agree closely with the American Standard, as explained in the footnote on p. C1 of the S. A. E. HANDBOOK. To avoid duplication, and the possibility of error arising therefrom, reference should be made to the American Standard only, or to the transcripts therefrom in the S. A. E. HANDBOOK.

ARMY-NAVY STANDARDS ADOPTED

Result of First Joint Army-Navy Conference Held in June, 1924

As the result of the first joint conference, held at the Naval Aircraft Factory in Philadelphia on June 28, 1924, between the Army Air Service and the Bureau of Aeronautics of the Navy Department about 50 standards have been officially approved as AN or Army-Navy Standards. The purpose of the Conferences is to eliminate the differences in the specifications and requirements for the standard parts of the Army Air Service and the Navy and to adopt a uniform system of standards. The advantages of such a procedure will be self-evident to those who have in the past been obliged to carry duplicate stocks of so-called standard parts necessitated by slight differences in the Army and Navy requirements. The standards adopted are listed hereinafter, as it is believed that members will be interested in obtaining copies of certain of the specificatons from the proper authorities.

ARMY-NAVY STANDARDS ADOPTED TO DATE

AN-11	Cotter-Pins
AN-12 to AN-18	Flat-Head Pins
AN-19	Thimbles
AN-20	Shackles
AN-21	Pulleys
AN-22	Flat Steel Washers for Wood
AN-23 to AN-29	Streamline Tie-Rods
AN-30	Rigid Terminals
AN-31	Hose Liners
AN-44 to AN-50	Turnbuckles

It is not intended to have the new AN Standards render the existing Army and Navy standards immediately obsolete. In practically all cases the old and the new standards are interchangeable, or the old can be readily converted to the new by minor modification. Where it is impracticable to make the conversion, the Army and Navy will accept parts conforming to the old standards until the supply on hand is exhausted. Manufacturers of standard parts will receive waivers on orders calling for the new standards so that they may deliver material conforming to the old standards where it is shown that the material was manufactured before the promulgation of the AN Standards. It is desired, however, that new parts, made after such promulgation, be in accordance with the AN Standards.

MINIMUM CLEARANCE OF 3 IN. NECESSARY

Spark-Plug Operation Affected If Metallic Objects Are Too Near Terminal End

According to O. C. Rohde, who was chairman of the Subdivision that developed the present S. A. E. Spark-Plug Standard, there has been a tendency in the last year to locate metal covers or other metallic parts too near to the terminal end of spark-plugs, resulting in short-circuiting under certain conditions of operation. Mr. Rohde believes that this is a matter that should be given proper attention by designing engineers, as there are certain definite limits which must not be exceeded if spark-plugs are to operate properly.

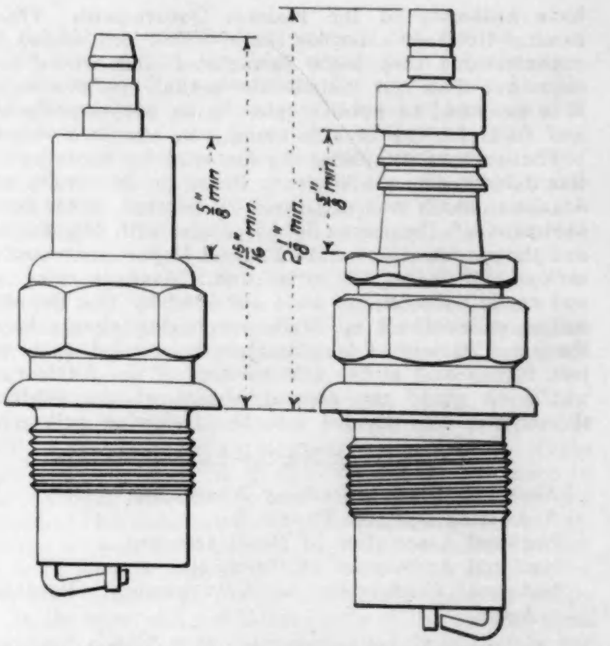


FIG. 1—MINIMUM DISTANCE FROM GASKET SEAT TO TOP FOR S. A. E. STANDARD ⅞ IN.-18 SPARK PLUGS

The present spark-plug standards, which a recent survey indicated were used by 78 per cent of all manufacturers, are most important, not only from an engineering, but also from a merchandising and service, basis. In the present standards there are certain limits in overall lengths that cannot be changed unless all of the accepted standards are violated.

The minimum distance from the top of the spark-plug shell or bushing to the metallic terminal connection is ⅝ in. and to insure absolute safety from the spark jumping this distance, it should be 11/16 in. The minimum clearance between the spark-plug terminal and the nearest metallic object should not be less than ⅜ in. With the standard ⅞-in.-18 spark-plug having the distance from the gasket seat to the top the minimum, the dimensions shown in Fig. 1 obtain. It is readily apparent that further shortening of the distance from the gasket seat to the top is impossible without changing the interior design of the spark-plugs.

Mr. Rohde believes that if designing engineers will accept 3 in. as the minimum distance between the spark-plug gasket-seat and the nearest metallic object above the spark-plug, it will be possible for the present standard spark-plugs as made by different manufacturers to be used without requiring any special design as has been the case in several instances in the last year.

NATIONAL DIRECTORY OF SPECIFICATIONS

Guide to 6000 Commodity Specifications To Be Published by Government

Distribution of a National Directory of Commodity Specifications by the Government Printing Office is expected to begin about July 1, next. This new publication will contain references to specifications for over 6000 commodities or groups of commodities, as issued by Federal, State and municipal governments, engineering societies and trade associations. It will be a bound volume of standard catalog size, within the range of 7½ x 10¾ in. and 7⅝ x 10⅝ in., and the price probably will be $2 per copy.

It is believed that this directory will be of appreciable value to members of the Society and their companies and that it will influence more extensive application of standardization in the automotive industries for which the Society has been working for nearly 15 years. Distinctive markings will indicate the specifications formulated by national technical societies and trade associations having national recognition and by other organizations that represent industry or

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Mirrors.—All motorcoaches shall be provided with an inside mirror

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Destination and Route Signs.—A route sign shall be located over the windshield on all motorcoaches and so placed and illuminated that it may be read day or night from at least 70 ft. ahead of the vehicle. It must not interfere with the driver's vision or produce an annoying glare

Overhang of Body.—The maximum rear overhang of the motorcoach body beyond the center-line of the rear-axle shall be 7/24 of the overall length of the chassis

Height of Chassis Frame.—The maximum height of the frame, measured from the ground level to the top of the frame, without payload, shall be 35 in.

Brakes.—Motorcoaches equipped with only one set of wheel brakes shall have two distinct methods of operating them

Wheel-Housing.—The construction of rear wheel-housings shall be such that no damage can result from bursting tires. The construction of the fenders shall be such that no undue accumulation of dirt or foreign matter can be deposited on the body

Exhaust.—The arrangement of the exhaust piping shall be such that the passengers will be adequately protected from the exhaust gases.

To Review Standards and Recommended Practices

Inasmuch as the Motorcoach Division is a new one, having been established at the beginning of this administrative year of the Society, the Standards and Recommended Practices already adopted by the Society and published in the S.A.E. Handbook were scheduled for review with the purpose of designating those that are adaptable to motorcoach construction. As this work is completed by the Division, the Standards and Recommended Practices so approved will be thus indicated in the S.A.E. Handbook.

The Society's Motorcoach Committee last year cooperated closely with the Equipment Committee of the American Electric Railway Association and the plans of the Division for this year's work include the continuation of this close contact. Those present at the meeting of the Division were:

G. A. Green, Yellow Coach Mfg. Co., *Chairman*
R. S. Burnett, Standards Manager, Society of Automotive Engineers, Inc.
Charles Froesch, International Motor Co.
G. E. A. Hallett, General Motors Research Corporation
William T. Lutey, Lang Body Co.
R. E. Plimpton, *Bus Transportation*
A. J. Scaife, White Motor Co.
P. V. C. See, Northern Ohio Traction & Light Co.

NEW SCREW-THREAD DESIGNATIONS

In view of the recent Society approval of the report of the Screw-Threads Division on Screw-Thread Fits, the method of designating screw-threads and fits, which is recommended in the American Standard for Screw-Threads and which will be used in the future in the S. A. E. Handbook, should be adopted in general shop practice in order that those in the industry may "speak the same language."

The basis of the system of identification is the initial letter of the thread series followed by the number of the class of fit. The thread series are designated as

F—Fine Series (S. A. E. Regular)
C—Coarse Series (U. S. Standard)

The fit classifications recommended in the American Standard and reprinted in the S. A. E. Handbook are designated as

Loose Fit—Class 1
Free Fit—Class 2
Medium Fit—Class 3

Thus a threaded part of 1-in. diameter with 14 threads per inch and with the Free (or Class 2) fit would be indicated as

1″-14-NF-2

ard because it is used in the report of the National Screw Thread Commission and it is desired to have all practice in the Country uniform. If the thread is left-hand, the symbol LH follows the number of threads. No symbol is used to designate right-hand threads. If the above example were intended for designating a left-hand thread, it would therefore be indicated as

1″-14-LH-NF-2

The fit classifications applicable to automotive work are printed in the S. A. E. HANDBOOK beginning on p. C1. The complete American Standard for Screw-Threads can be also obtained in pamphlet form. The specifications issued by the National Screw Thread Commission agree closely with the American Standard, as explained in the footnote on p. C1 of the S. A. E. HANDBOOK. To avoid duplication, and the possibility of error arising therefrom, reference should be made to the American Standard only, or to the transcripts therefrom in the S. A. E. HANDBOOK.

ARMY-NAVY STANDARDS ADOPTED

Result of First Joint Army-Navy Conference Held in June, 1924

As the result of the first joint conference, held at the Naval Aircraft Factory in Philadelphia on June 28, 1924, between the Army Air Service and the Bureau of Aeronautics of the Navy Department about 50 standards have been officially approved as AN or Army-Navy Standards. The purpose of the Conferences is to eliminate the differences in the specifications and requirements for the standard parts of the Army Air Service and the Navy and to adopt a uniform system of standards. The advantages of such a procedure will be self-evident to those who have in the past been obliged to carry duplicate stocks of so-called standard parts necessitated by slight differences in the Army and Navy requirements. The standards adopted are listed hereinafter, as it is believed that members will be interested in obtaining copies of certain of the specificatons from the proper authorities.

ARMY-NAVY STANDARDS ADOPTED TO DATE

AN-11	Cotter-Pins
AN-12 to AN-18	Flat-Head Pins
AN-19	Thimbles
AN-20	Shackles
AN-21	Pulleys
AN-22	Flat Steel Washers for Wood
AN-23 to AN-29	Streamline Tie-Rods
AN-30	Rigid Terminals
AN-31	Hose Liners
AN-44 to AN-50	Turnbuckles

It is not intended to have the new AN Standards render the existing Army and Navy standards immediately obsolete. In practically all cases the old and the new standards are interchangeable, or the old can be readily converted to the new by minor modification. Where it is impracticable to make the conversion, the Army and Navy will accept parts conforming to the old standards until the supply on hand is exhausted. Manufacturers of standard parts will receive waivers on orders calling for the new standards so that they may deliver material conforming to the old standards where it is shown that the material was manufactured before the promulgation of the AN Standards. It is desired, however, that new parts, made after such promulgation, be in accordance with the AN Standards.

MINIMUM CLEARANCE OF 3 IN. NECESSARY

Spark-Plug Operation Affected If Metallic Objects Are Too Near Terminal End

According to O. C. Rohde, who was chairman of the Subdivision that developed the present S. A. E. Spark-Plug Standard, there has been a tendency in the last year to locate metal covers or other metallic parts too near to the terminal end of spark-plugs, resulting in short-circuiting under certain conditions of operation. Mr. Rohde believes that this is a matter that should be given proper attention by designing engineers, as there are certain definite limits which must not be exceeded if spark-plugs are to operate properly.

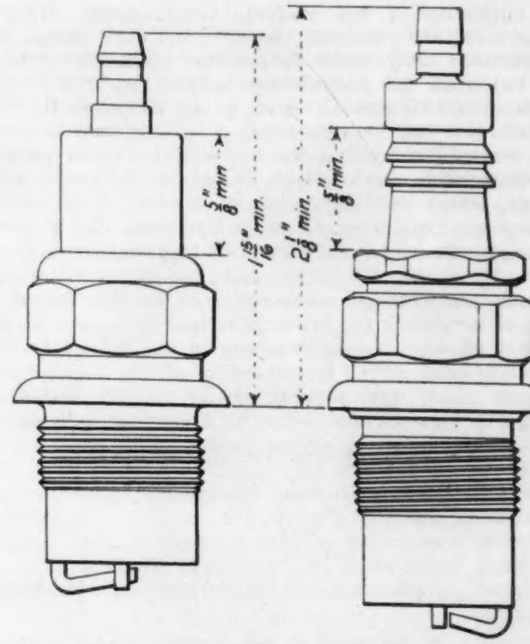

FIG. 1—MINIMUM DISTANCE FROM GASKET SEAT TO TOP FOR S. A. E. STANDARD ⅞ IN.-18 SPARK PLUGS

The present spark-plug standards, which a recent survey indicated were used by 78 per cent of all manufacturers, are most important, not only from an engineering, but also from a merchandising and service, basis. In the present standards there are certain limits in overall lengths that cannot be changed unless all of the accepted standards are violated.

The minimum distance from the top of the spark-plug shell or bushing to the metallic terminal connection is ⅝ in. and to insure absolute safety from the spark jumping this distance, it should be 11/16 in. The minimum clearance between the spark-plug terminal and the nearest metallic object should not be less than ⅝ in. With the standard ⅞-in.-18 spark-plug having the distance from the gasket seat to the top the minimum, the dimensions shown in Fig. 1 obtain. It is readily apparent that further shortening of the distance from the gasket seat to the top is impossible without changing the interior design of the spark-plugs.

Mr. Rohde believes that if designing engineers will accept 3 in. as the minimum distance between the spark-plug gasket-seat and the nearest metallic object above the spark-plug, it will be possible for the present standard spark-plugs as made by different manufacturers to be used without requiring any special design as has been the case in several instances in the last year.

NATIONAL DIRECTORY OF SPECIFICATIONS

Guide to 6000 Commodity Specifications To Be Published by Government

Distribution of a National Directory of Commodity Specifications by the Government Printing Office is expected to begin about July 1, next. This new publication will contain references to specifications for over 6000 commodities or groups of commodities, as issued by Federal, State and municipal governments, engineering societies and trade associations. It will be a bound volume of standard catalog size, within the range of 7½ x 10¾ in. and 7⅝ x 10⅝ in., and the price probably will be $2 per copy.

It is believed that this directory will be of appreciable value to members of the Society and their companies and that it will influence more extensive application of standardization in the automotive industries for which the Society has been working for nearly 15 years. Distinctive markings will indicate the specifications formulated by national technical societies and trade associations having national recognition and by other organizations that represent industry or

have authority of the Federal Government. This forthcoming directory classifies the specifications, shows by what organizations they were formulated and where to secure them but does not include the actual specifications, which it is proposed to publish later in an encyclopedia of looseleaf form for top or side binding in standard ring-binders.

The work of compiling the material for these publications was delegated to an Advisory Board on Dictionary of Specifications, which was organized in October, 1923, by the Department of Commerce to cooperate with the Department, and the specifications of 19 Federal Departments and organizations, 22 States, 17 cities and 150 engineering societies and trade associations were collected by the Board. Difficulties encountered by State purchasing agents because of the great variety of specifications in use led up to the project, it was said at the first meeting of the Advisory Board, which, to study the several phases of the subject more thoroughly, was divided into the following subcommittees:

COMMITTEE NO. 1—CLASSIFICATION

American Electric Railway Association
Associated Business Papers, Inc.
National Association of Manufacturers
National Association of Purchasing Agents
National Conference of Governmental Purchasing Agents

COMMITTEE NO. 2—FORM AND SIZE

American Hotel Association
Associates for Government Service
National Conference of Business Paper Editors
National Conference of Governmental Purchasing Agents
Society of Automotive Engineers

COMMITTEE NO. 3—SCOPE

American Engineering Standards Committee
American Hospital Association
American Society for Testing Materials
Chamber of Commerce of the United States of America
National Association of Purchasing Agents
National Electric Light Association

The original classification of specifications comprised 21 groups of commodities but these were rearranged at the recommendation of Committee 1 into 10 major groups, with divisions and subdivisions arranged by the Dewey decimal system, the major groups being shown in the accompanying table.

The directory will also include a foreword, introduction, and an alphabetical "finding list" of commodities for which specifications have been prepared.

Present Decimal Class	Classification of Commodity Groups	Commodities Indexed	Number of Specifications
000	Animals and Animal Products	350	431
100	Vegetable Food Products, Oil, Seeds, Expressed Oil and Beverages	525	695
200	Other Vegetable Products (Except Fibers and Wood)	400	95
300	Textiles	275	73
400	Wood and Paper	625	735
500	Non-Metallic Minerals	725	664
600	Ores, Metals and Manufactures, Except Machinery and Vehicles	1,400[a]	6,400
700	Machinery and Vehicles	800[a]	2,900
800	Chemicals and Allied Products	600	231
900	Miscellaneous	650	441

[a] Estimated.

Committee No. 3 recommended that provision be made for a very flexible system so that the material may be published in a variety of forms as may seem best suited to the various types of specification and to conditions as they may arise in carrying through the project. It also recommended that notes be included describing the field that the various specifications cover, how they may best be used and other information regarding their listing and use.

At a meeting of the Advisory Board in the City of Washington on Feb. 27, last, it was decided to issue the directory under the main title of National Directory of Commodity Specifications with descriptive sub-titles, and it was reported that part of the manuscript was then in the Government Printing Office.

It had been planned to reprint complete or extracted specifications in the encyclopedia when issued, but the disadvantages of so doing were pointed out at the meeting, and it was decided to delay publishing the encyclopedia until the use of the directory indicates more clearly what would be the best form in which to publish the encyclopedia, but to issue a supplement to the directory treating of the natural limitations of specifications and their selection and use by purchasers and producers.

With regard to the availability of specifications to users thereof, it was said that practically the only ones not easily obtained are some of those for foodstuffs but that nearly all others can be had from the various organizations formulating the specifications that are listed in the directory. Some consideration was given to a suitable central agency for distributing such specifications as are not published generally, but no definite arrangements for such distribution have as yet been made.

The Society is represented on the Advisory Board by General Manager Coker F. Clarkson and Standards Manager R. S. Burnett as alternate, to whom inquiries or comments in connection with the National Directory of Commodity Specifications should be directed at the Society's headquarters.

SCREW-THREAD STANDARD DISCUSSED

Division Correspondence Indicates Misunderstandings Still Exist

Although the present S.A.E. Standard for Screw-Thread Fits and Tolerances was adopted in February, 1924, some misunderstandings still exist as to its application. The following extracts of correspondence between the S.A.E. Screw-Threads Division and a manufacturer of screw-machine products should be of interest to members of the Society who are using, or are considering the use of, the American (S.A.E.) Standard for Screw-Threads.

A difference of opinion prevails in the machine-screw industry today as to whether the dimensions specified in the American Standard for Screw-Threads are intended to apply to the finished product or to the gages used therefor, and consequently whether the Free or Medium Fit should be used.

It is my understanding of the standard that it must actually be the measurements of the gages and not of the product to prevent interference between the mating parts. Presuming that I am right, I favor the adoption of Class 2, which, after it is reduced by a gage manufacturer's tolerance, provides or rather eliminates interference, and reduces the extreme tolerance of Class 2 to a proper amount which is actually favorable to the old American Society of Mechanical Engineers Standard. Class 3 will probably be used if the extreme sizes are not reduced by a gage manufacturer's tolerance.

Should your reply to the above inquiry be to the effect that the product should measure according to this new standard, do you believe no actual interference will be found although the maximum of the screw and the minimum of the nut are of the same basic size?

Replying to your inquiry, I would say that, broadly speaking, the dimensions given in the tables are for the threads of the product. Speaking precisely, however, it is impossible to know the exact dimensions of the product except through measuring instruments, such as the screw-thread gage, nut plug, thread micrometer or the comparator. Consequently what is called the size of the screw is merely the reading of or the size to which the measuring instrument is set.

To make certain that the product does not exceed the limits, the measuring instrument or the gage must not obviously exceed the limits; furthermore, it is at once apparent that the more accurate the measuring instrument or gage, the more closely is it possible for the screw product measured therewith to approach the specified limits. In practice, the limits in the screw product, therefore, will fall inside of the specified limits, the amount depending upon the inaccuracies in the measuring instruments, or the methods of measuring; in other words, the more accurate the gages, the greater the tolerance in the manufacture of the product.

In the last analysis, any dispute between producer and user as to whether screw-thread product is within the limits or not might have to be determined by a procedure such as the following: Assuming the product is acceptable to the manufacturer's gages, but not to the purchaser's gages, comparison of the purchaser's gages would be made with standard reference or master plugs, made within very close limits to the dimensions given in the specifications. It is necessary that a record should be made by some one organization, for instance the Bureau of Standards, showing the errors existing in the master plugs.

In the writer's experience, this procedure has occasionally had to be resorted to and in each case the customer has been satisfied and the work acceptable.

Among the measuring instruments cited above is the thread micrometer. Inasmuch as this instrument measures merely the pitch diameter at one place in the thread, it cannot take into account rotundity, parallelism or lead error; as a consequence, screw threads that this instrument might show to be within limits might actually be outside the limits when all the gaging factors are taken into consideration as they should be. Unless the screw-thread product is round, parallel and free from lead errors within the length of engagement, the thread micrometer is not to be relied upon as a substitute for methods of gaging that simultaneously take into account factors of lead and rotundity as well as the diameter.

It should be noted that it was originally proposed by the National Screw Thread Commission that the gaging system include master, inspection and working gages, the master gages being as close as possible, but within the specified "extreme" limits, the inspection gages within narrower limits and the working gages within still narrower limits, so that to be sure of acceptance the work itself had to be within the extreme limits by a considerable amount equal to the accumulative errors in the three series of gages. Upon the completion of the work by the National Screw Thread Commission, all that was left of this system was the master gage factor. The Sectional Committee has made but slight reference to the gaging factor, on the assumption that the screw-thread product should be acceptable, if made as close to the limits as the most accurate gages or measuring instruments will permit.

You will see from the above that it is theoretically possible that the product itself should be acceptable to the extreme limits; inasmuch as the limits cannot be exceeded and it is commercially impracticable to have gages without errors, the question resolves itself into one of gage accuracy and the limits of the screw product must, therefore, be expressed in terms of the gage size.

I would say that you are right in your inference that no danger of interference between the mating parts exists, even though the basic size is both the minimum for the nut and the maximum for the screw. In this connection, however, there are at least two things that we must always bear in mind, and they are that (*a*) a limit gage measures the absolute limit both in itself and in the product; in other words, the gage itself must not be outside the limits, neither must any work be accepted by a gage that is worn or a micrometer caliper that only measures one of the elements, pitch diameter, be permitted to let product pass that is outside the limit and (*b*) the more imperfections there are in the product, the looser will be the fit of engaging parts, even though those parts are a close fit in a gage and on a plug that are exactly to the basic size.

Placing the proper construction on limits, that they must include 100 per cent of the product, I believe it will be found that the tolerances in the Free Fit Class are none too large, as on the average the tolerance in the product will not be more than two-thirds of the specified tolerances; if in the manufacture, an attempt is made to take advantage of the full tolerance, it is very likely that gage wear may allow some of the product to be made outside the actual specified limits.

In the past, and not infrequently at the present time, we "get away" with a product that falls outside the limits, and as this is serviceable and not complained of by the customer, we think we are working to the limits when in reality we are not. I think this very fact misleads very many manufacturers who think that Free Fit Tolerances are too liberal, and that they could easily work within the Medium Fit Tolerances.

Your recent letter completely answers my questions on the subject of screw-thread tolerances. The information is greatly appreciated as it confirms exactly my understanding of the measurements in the American Standard for Screw-Threads. As the product must be kept within the extreme measurements, the Free Fit (Class 2) appears as none too liberal for machine-screw work.

USE OF PREFERRED NUMBERS

Committee Appointed To Study Their Use Wants Comments from the Industry

A description of the basic plan of preferred numbers and their application in the designing of series of sizes of manufactured products was printed in the February, 1925, issue of THE JOURNAL on p. 140h. The Special Committee appointed by the American Engineering Standards Committee to study this subject, on which Cornelius T. Myers represents the Society, desires the comments and suggestions of engineers and executives regarding their experience with the use of such a system and its application to their products. The members of the Society, as well as others in the industry who may be interested in this subject, are urged to furnish the desired information through the Society's office.

STANDARDS ACCEPTED BY THE SOCIETY

March Issue of Data Sheets Contains Recommendations Approved at Annual Meeting

In accordance with the Standards Committee Regulations, the recommendations that were approved by the Standards Committee at the 1925 Annual Meeting in Detroit, and confirmed by the Council and Society action at the Annual Business Meeting were submitted by letter ballot to the voting members of the Society. The results of the letter ballot, returnable Feb. 28, indicate that no relatively large minority

is opposed to the adoption of any of the recommendations. The comments submitted in support of the few negative votes cast were of such a nature that it was considered justifiable to refer them to the proper Divisions of the Standards Committee for consideration at the next meetings held.

The complete vote on all the recommendations balloted upon is recorded in the accompanying tabulation. The first column gives the number of affirmative votes cast; the second, the number of negative votes; and the third, the number of members who voted neither way.

	Yes	*No*	*Not Voting*
AXLE AND WHEELS DIVISION			
Differentials	230	3	76
ELECTRIC VEHICLE DIVISION			
Battery-Tray Terminal-Lugs	221	0	88
ENGINE DIVISION			
Engine Support Arms	235	0	74
Flywheel Housings	237	0	72
LIGHTING DIVISION			
Head-Lamp Doors	223	3	83
Head-Lamps	226	1	82
NON-FERROUS METALS DIVISION			
Wrought-Aluminum Bronze	228	0	81
PARTS AND FITTINGS DIVISION			
Compression-Type Tube Fittings	235	4	70
Flexible-Discs	236	0	73
License-Plate Bracket-Slots	235	0	74
PASSENGER-CAR BODY DIVISION			
Door Hinges	208	0	101
SCREW-THREADS DIVISION			
Gaging of Castle-Nut Slots	244	0	65
Screw-Thread Fits	241	1	67
Tap-Drill Reference Tables	244	0	65
STORAGE-BATTERY DIVISION			
Automobile Storage Batteries	226	1	82

The report on Head-Lamp Doors was voted upon subject to the approval of the Special Committee on Standardization Policy and this report will, therefore, not be included in the March issue of data sheets as the Special Committee has not acted. The report on Compression-Type Tube Fittings as approved by the Standard Committee was limited to the ⅛, 3/16, ¼ and 5/16-in. sizes only. The larger sizes are still subject to criticism and have been referred back to the Parts and Fittings Division for further study.

The March issue of data sheets containing the new and revised recommendations approved by letter ballot will be issued during the present month. The S.A.E. HANDBOOK with the new and revised data sheets will contain 594 pp.

This is a larger number of pages than the Vol. I binders can conveniently accommodate and consequently it has been found advisable by many members to divide the Handbook into two parts, retaining Sections A to C, inclusive, in the old binder and putting the remaining sections in a new binder, both being marked to indicate the sections that they contain.

Members should bear in mind that the S.A.E. HANDBOOK is arranged so that in case they are not interested in certain classifications of standards, the respective sections can be removed from the Handbook without destroying its general arrangement.

MOLYBDENUM STEELS APPROVED

Four Analyses Proposed by Iron and Steel Division for Recommended Practice

At the meeting of the Iron and Steel Division held in Buffalo on March 10 four definite chemical compositions were approved for Molybdenum Steels for adoption as S.A.E. Recommended Practice. These compositions were based on a report submitted by J. D. Cutter of the Climax Molybdenum Co., who served as a Subcommittee of the Subdivision on Chromium and Chromium-Vanadium Steels. The numbers adopted for these compositions, which are given in the accompanying table, are in the 4000 series which was reserved by the Iron and Steel Division for this type of steel in its report approved by the Society in March, 1922.

MOLYBDENUM STEELS SPECIFICATIONS RECOMMENDED

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Maximum	Sulphur, Maximum	Chromium Range	Nickel Range	Molybdenum Range
4130	0.25-0.35	0.40-0.70	0.04	0.045	0.50-0.80	....	0.15-0.25
4140	0.35-0.45	0.40-0.70	0.04	0.045	0.80-1.10	....	0.15-0.25
4150	0.45-0.55	0.40-0.70	0.04	0.045	0.80-1.10	....	0.15-0.25
4615	0.10-0.20	0.30-0.50	0.04	0.045	....	1.25-1.75	0.20-0.30

PAUL R. MOFFETT

THE death of Paul Raymond Moffett at the University Hospital, Philadelphia, on March 8, is reported. He had suffered with heart trouble for some time and, after being confined to bed for about 6 weeks, was moved to the hospital. He leaves a father, mother, two brothers and a sister.

The deceased, who was 40 years of age, was manager of automotive sales for the Electric Storage Battery Co. at Philadelphia. He had been with the company 14 years and was engaged for a number of years in work on batteries used in starting, lighting and ignition systems for motor vehicles, being located in Cleveland. He was born in Williamsport, Pa., and held the degree of bachelor of science in electrical engineering from the University of Michigan. He had been an Associate Member of the Society since 1914 and was actively identified with the affairs of the Pennsylvania Section. He was also a member of the Automotive Electric Association and the Penn Athletic Club. During the war he was in the Aviation Corps of the American Expeditionary Force and at the close of the war was discharged with the rank of captain.

FRED H. BERGER

FOLLOWING an operation for cancer, Fred H. Berger died at the Grace Hospital, Detroit, on the morning of March 24. Mr. Berger, who was a mechanical engineer specializing in automotive engineering, had been a member of the Society since 1910, at which time he was engineer and designer for the Russell Motor Axle Co., of Detroit. Subsequently, for several years, he was engineer for the Oakland Motor Car Co., and for the last 2 years held a similar position with the Yellow Cab Co., making his headquarters in Detroit.

He was born at Bingen, Germany, June 17, 1879, and received the degree of mechanical engineer at the Polytechnicum. After working for 5 years with the Daimler Motor Works, the Siemens Schuckert Works and the Prometheus Machine Works, in Berlin, he came to this Country 18 years ago. His early connections here were with the Gearless Motor Car Co. and James Cunningham, Son & Co., Rochester, N. Y., and the Buick plant of the General Motors Co., Flint, Mich. He had no relatives in America.

Vol. XVI April, 1925 No. 4

The Personal Equation in Automobile Driving

By F. A. Moss[1] and H. H. Allen[2]

METROPOLITAN SECTION PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

ABSTRACT

ALTHOUGH many variables enter into the personal equation of the driver of an automobile, this paper concerns principally his reaction-time. The tests described had for their objects the determining of (*a*) the average time that elapses between the hearing of a signal, such, for example, as the shot of a pistol, and the applying of the brake; (*b*) the relation between the reaction-time and the variability of the individual; and (*c*) the effect on reaction-time of such factors as the speed of driving, training, age, sex, race and general intelligence.

The reaction-time was determined by two pistols mounted on the under side of the running-board of an automobile and pointed toward the ground, the first being fired by the experimenter when the car had reached the desired speed, the second, by the person under test in making the initial motion of applying the brake-pedal. The shells used, being loaded with red lead, made bright spots on the road, the distance between which could be measured accurately. The ratio of this distance, measured in feet, to the speed of the car, in feet per second, gave the reaction-time. The subjects of the test included 36 students from George Washington University, including 10 female students; 11 colored students from Howard University; and 10 taxicab drivers. Each person was tested at speeds of 10, 15, 20, 25 and 29½ m.p.h. An average reaction-time for the total number of 285 runs was found to be 0.54 sec. Variability was determined by subtracting the shortest reaction-time of each person from the longest and dividing the difference by two. When these results were plotted against the reaction-time of the various persons, the surprisingly high correlation factor, 0.822, was obtained.

The conclusions reached were that the reaction-time (*a*) is not appreciably affected by the speed of driving, (*b*) may be reduced by training, (*c*) is not affected by age or sex and (*d*) is related to general intelligence. The number of data at hand was insufficient to show what, if any, is the influence of race.

THUS we find among children those who are slow and sure, slow and erratic, quick and sure, quick and erratic, and no one seriously expects these tendencies to be altered any more than he expects the leopard to change his spots. These permanent peculiarities we call the personal equation.—*Seashore.*

In many fields of activity the presence of the so-called personal equation has been definitely established and due allowance is made for it. In few occupations is the existence of the personal equation more evident than in that of automobile driving. It was the desire to learn more about the influence of this factor that prompted the experiments described below.

It may be well to point out the fact that many more variables enter into the personal equation in driving than are here discussed. In any line of investigation, branches may lead the experimenter into useful fields of study. Practical considerations, however, naturally limit scope and do not always admit of studying every possible variable. It will be realized, therefore, that such considerations as the effects on reaction-time of fatigue and of continuous driving at high speed have not been disregarded because of their unimportance but because of the necessity for limiting the scope of this paper. In addition to this, fatigue norms have been established in various lines of motor activity that are comparable, it is believed, to those that might have been found had the scope of these experiments been broad enough to include such considerations.

The objects of the experiments were:

(1) To determine the average time elapsing between the hearing of a signal, as, for example, the shot of a pistol, and the applying of the brake

(2) To determine the relation between the reaction-time and the variability of an individual

(3) To determine whether a relation exists between the speed at which an individual is driving, when he receives a signal, and his reaction-time; in other words, whether his reaction-time will be longer or shorter, when driving at the rate of 30 m.p.h., than when driving at the rate of 10 m.p.h.

(4) To determine how the reaction-time is affected

(5) To determine the relation, if any, between reaction-time and age

(6) To determine whether an appreciable difference, as regards reaction-time, exists between the sexes

(7) To determine the effect of race upon average reaction-time

(8) To determine the relation between reaction-time and other conditions, such as those of general intelligence

DESCRIPTION OF APPARATUS

To carry out these experiments, apparatus was devised that consisted of two revolvers mounted securely on the under side of the running-board of an automobile and pointed toward the road, as shown in Fig. 1. One revolver was fired by the experimenter as a signal, and the other by the person under test in making the initial motion of applying the brake-pedal. Shells loaded with red lead were employed, so that, when each gun was fired, a bright red spot was made upon the road.

As the success of the method used is largely dependent upon the accuracy of the speed measurements, the ordinary speedometer was discarded and a chronometric tachometer of very high accuracy connected with the transmission was used instead. The position of the tachometer is shown in Fig. 2.

The individuals tested in these experiments comprised three groups: (*a*) 36 students from George Washington University, including 10 female students; (*b*) 11 colored

[1] Staff psychologist, Bureau of Public Personnel Administration, City of Washington.

[2] Assistant mechanical engineer, automotive powerplants section, Bureau of Standards, City of Washington.

Fig. 1—Method of Mounting Pistols under Running-Board
The First Is Fired by the Experimenter, the Second by the Person under Test, in Applying the Brake-Pedal. Shells Loaded with Red Lead Make Bright Red Spots on the Road

students from Howard University, and (*c*) 10 taxicab drivers from the Black & White Taxicab Co. of the City of Washington. All of them had previous experience in driving cars with standard gear-shifts so, for that reason, the element of unfamiliarity with the machine was not very important. Each person, after being seated at the steering-wheel, was given the following instructions before starting:

> You are to watch the needle of the tachometer. For your first test, keep your foot on the accelerator with sufficient pressure to hold the needle steady, with the least possible movement, at 180 r.p.m. Remember that it is necessary to hold it at 180 r.p.m. for some distance before you will hear the signal to stop the machine. For the second test, you will hold it at 270 r.p.m.; for the third, at 360; for the fourth, at 450; and so on. After the needle has reached 180 r.p.m., I shall pull the wire discharging the first pistol. As soon as you hear the report of the shot, put your foot on the brake, as if to stop the machine. Remember that you will have to hold your foot on the accelerator, with an even pressure, to keep the machine at 180 r.p.m. until your hear the pistol fired. Then move your foot as quickly as possible, just as if it were necessary to stop the machine to avoid a serious accident.

The machine was then started and, after the operator had become sufficiently familiar with it to become perfectly at ease, he was told to throttle down to 180 r.p.m. To prevent the driver from expecting the pistol to be fired immediately on reaching 180 r.p.m., the machine was allowed to go for some distance after reaching this speed before the experimenter discharged the first pistol. Upon hearing the signal, the operator moved his foot immediately to the brake, a very slight movement of which discharged the second pistol. The machine was then stopped and the distance between the two red spots on the road left by the pistol shots was measured to the nearest 0.01 ft. (See Fig. 3.) The same method of procedure was repeated for speeds of 270 r.p.m. (15 m.p.h.), 360 r.p.m. (20 m.p.h.), 450 r.p.m. (25 m.p.h.) and 530 r.p.m. (29½ m.p.h.).

Fig. 2—Position of Chronometric Tachometer
Because of Its Greater Accuracy, This Instrument Was Used Instead of the Usual Speedometer

Average Reaction-Time

As each of the 57 drivers made the runs at the five different speeds, there was a total of 285 runs or reactions from which to determine the average reaction-time for this operation. To determine the reaction time, it was necessary, in each instance, to divide the distance, in feet, shown between the two red spots on the pavement caused by the discharge of the pistols, by the speed, in feet per second, at which the machine was going when the pistols were discharged. Allowance was made, of course, for the distance between the two guns. The average reaction-time for the 57 subjects, each with five different tests, amounted to 0.54 sec., or slightly more than ½ sec. In other words, a person having the average reaction-time and traveling at the rate of 30 m.p.h., would have traveled approximately 22 ft. after hearing the signal before he began to apply the brakes of the machine. The time required to cover this distance of 22 ft., in this particular case, is what has been defined as reaction-time.

The drivers varied very widely in their reaction-times. Some persons in the group tested have a reaction-time as low as 0.31 sec., while others show a reaction-time as high as 1.02 sec. Owing to the fact that the persons who submitted to the tests were either university students or taxicab drivers, it is reasonable to believe that the groups tested have a shorter mean reaction-time than would an average person. There is little doubt that many drivers could be picked up on the street who would have reaction-times as long as 1.5 or even 2.0 sec. The practical significance of this assumption will be discussed in a later section.

Variability

It is an interesting question whether persons who have the longer reaction-times are more constant in their speeds of reaction than are persons with shorter reaction-times. To determine this point the shortest reaction-time of each person was subtracted from the longest, and the result was divided by two. In this way, a measure of the variability of each person was secured. A correlation chart was made of the reaction-time against the mean of the variability. This gave the surprisingly high correlation factor, 0.822. Fig. 4 shows the correlation chart.

The significance of the correlation factor is as follows: If two factors that are to be examined for correlation are plotted against each other, and the highest values of one all concur with the highest values of the other, the next highest of the first with the next highest of the second, and so on, until the lowest values of both have been reached, the correlation is perfect, or +1.0. If, on the other hand, the lowest value of one variable corre-

sponds to the highest value of the other, the next lowest of the first to the next highest of second, and so on, the correlation is again perfect, but with the opposite sign, or —1.0. The first case represents a perfect direct relation, the second case, a perfect inverse relation. If the two variables so fall, with respect to each other, that one-half of the highest values of one correspond to one-half the highest values of the other, and the reverse is true for the remaining values, the correlation is zero. This means that none other than a chance relation exists between the two variables. As the correlation factor thus obtained approaches zero, whether it be either negative or positive, it becomes of less and less significance, and the greater becomes the evidence that the correlation shown is a chance one. On the other hand, the greater the magnitude of the correlation factor thus obtained, the greater becomes the probability that the relation is either a direct ratio or an inverse ratio, according to whether the sign be positive or negative.

As the positive correlation of +0.822, in the example cited above, is so high, the element of chance becomes relatively insignificant, and we may readily assume that, if this factor should remain as high for a larger number of cases as it is now, the persons with the shorter reaction-times would almost universally be those with the least variability.

This phase of the experiment may be generalized as follows: The persons having the shorter reaction-times

FIG. 3—SPOTS ON THE ROAD MADE BY DISCHARGING THE PISTOLS
The Distance between the Spots Could Be Measured to 0.01 Ft. The Ratio of This Distance to the Speed of the Car, in Feet per Second, Is the Reaction-Time of the Person under Test

also had the more constant reaction-times and were less subject to fluctuations in their performances, whereas the persons having the longer reaction-times varied most, sometimes showing a reaction-time much longer or much shorter than their average performance. At first glance, it may seem possible to explain this variation on the basis of experience in driving, but a more careful study of the situation will indicate that this is not the case. The two persons that showed the greatest variability in the group, namely, 0.62 and 0.72 sec., had been driving regularly for 15 and 4 years respectively, while the

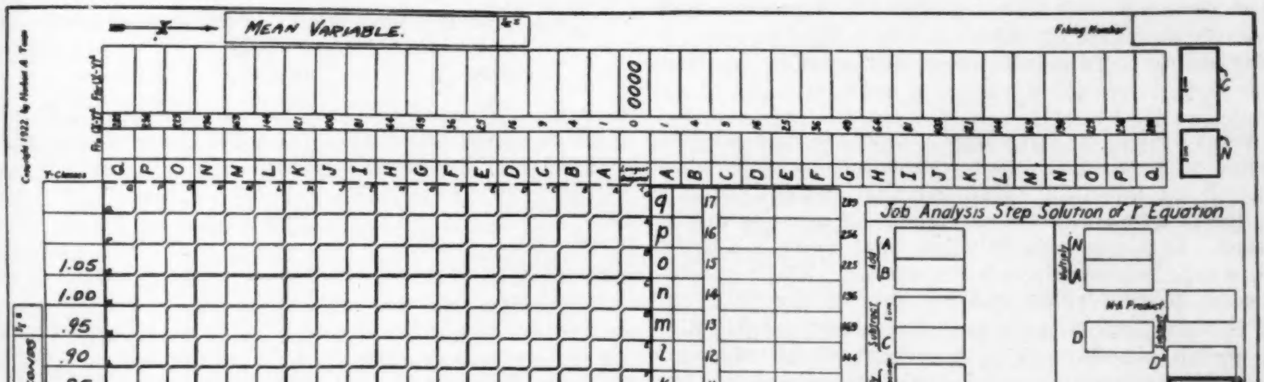

FIG. 4—RECTANGULAR CORRELATION SHEET
After Plotting the Results of the Tests, the Coefficient of Correlation Was Found To Have the Surprisingly High Value of 0.822

TABLE 1—AVERAGE REACTION-TIMES AT VARIOUS SPEEDS

Speed, M.P.H.	Reaction-Time, Sec.
10	0.65
15	0.54
20	0.52
25	0.48
30	0.49

persons that showed the least variability were three college students who had an average variability of 0.02 sec., their driving experience being 9, 3 and 3 years respectively.

SPEED

Statements have been made to the effect that an individual's reaction-time changes materially with the speed at which he is driving; for example, if he were driving at 10 m.p.h., he is supposed to show a radically different reaction-time from which he would show when driving at 40 or 50 m.p.h. To test this assumption, each individual was given a test at five different speeds: 10, 15, 20, 25 and 30 m.p.h. The average reaction-times for these five different speeds are given in Table 1.

With the exception of the first test, the average reaction-time shows little difference at the various speeds. The especially-long reaction time at 10 m.p.h. is the result of seven cases who seemed, in their first attempts, not to understand what they were to do. Disregarding these seven cases, the average reaction-time of the other 50 cases at 10 m.p.h. is 0.52 sec. which is comparable with the results obtained at other speeds. The element of practice leaves these results somewhat open to question.

TRAINING

To what extent an individual's reaction-time may be shortened with training has never definitely been determined. It is generally admitted that, within certain limits, the reaction-time for any group of muscles can be decreased. It is also generally held that there is a limit, beyond which improvement is impossible. These conclusions seem to find additional support in the data obtained in these experiments and presented in Table 2.

The graph shown in Fig. 5 indicates the effect of training on performance and enables a prediction to be made, with limitations as to the amount of improvement that an individual will make after a given number of years of experience in driving. From the data available, it would seem that this situation is best represented by the equation $y - 0.35 = 0.67 \times 10^{-0.28x}$, y being the reaction-time in seconds and x being the driving experience in years. The curve passing through the crosses is the curve of the equation, which approximates a smooth curve passing through the average observed results. The broken line passes through the average observed points. This curve is only typical of the curve of improvement with driving owing to the limited number of cases on which these data were collected; but it seems to fit in with various other curves of learning in motor activities. It would be preferable if a sufficient number of data could be obtained on the same persons that would show their improvement over a period of 8 or 10 years from the time they began driving. Unfortunately we do not have these data at present. Although the curve presented represents what is believed to be the typical improvement of an average driver, it would, no doubt, be eminently desirable to get learning curves of those who vary far on either side of the average reaction-time, of those who begin with a very short reaction-time and of those who begin with a very long reaction-time.

TABLE 2—VARIATION OF REACTION-TIME WITH TRAINING

Number of Years of Driving	Number of Individuals	Average Reaction-Time, Sec.
1	5	0.72
2	7	0.60
3	5	0.61
4	8	0.51
5	9	0.49
6	2	0.45
7	6	0.48
8	6	0.49
9	1	0.45
10	4	0.47
13	1	0.40
14	1	0.63
15	2	0.48

The value of a curve of this kind is readily apparent, for if it should be definitely established that persons who begin with a reaction-time of 0.70 sec. can shorten their reaction-time, after 2 years' driving experience, to 0.55 sec. then, from the standpoint of licensing operators, it would be possible to say immediately what one might expect the reaction-time of a driver to be some 2 years hence.

The data given may be generalized by saying that a tendency to shorten the reaction-time with an increase in the number of years of driving experience seems to exist. The same tendency is indicated by the data showing the superior ability of taxicab drivers, for these drivers are driving from 8 to 14 hr. every day in the week and show, on the whole, much shorter reaction-times than do the college students who drive very much less.

TABLE 3—VARIABILITY OF TAXICAB DRIVERS

Driver	Reaction-Time, Sec.	Variability, Sec.
A	0.31	0.05
B	0.32	0.05
C	0.38	0.06
D	0.38	0.04
E	0.38	0.04
F	0.40	0.05
G	0.46	0.10
H	0.46	0.10
I	0.47	0.07
J	0.48	0.19
K	0.50	0.30
Average for the Group, sec.	0.41	0.10

The good showing of the taxicab drivers may also have been due to the fact that the taxicab company in selecting the men naturally eliminated the men with the longer reaction-times; and this element of original selection should not be lost sight of, when the better showing made by the taxicab drivers over that of the other persons is considered. The average reaction-time of the taxicab drivers was 0.41 sec., whereas the average of the group as a whole was 0.54 sec. The average driving-experience of the taxicab drivers was 7.2 years, while the average driving-experience of the group as a whole was slightly less than 6.6 years. Attention should again be called to the fact that in a year a taxicab driver will drive from 15 to 20 times as much as will an average person, so that an apparent difference of 1 year's driving experience does not fully represent the situation.

It is also worth noting that the taxicab drivers were less variable than were the other persons examined. This may be attributed to two factors: (*a*) native con-

trol and (*b*) training. Table 3 shows the average reaction-time and variability of each of the 11 taxicab drivers, arranged in the ascending order of their reaction-times.

Age

It is generally recognized that it is more difficult to teach a person well advanced in years to drive an automobile than it is to teach an average youth of 17 or 18 years of age. Not only is it more difficult to teach older persons to drive an automobile, but they seem to have more trouble in learning to perform any motor acts of skill than do younger persons. An attempt has been made to explain this difficulty by blaming it on slower reaction-time. The facts obtained by these experiments, however, do not bear out this contention. The ages represented by the drivers ranged from 16 to 44. The data are presented in Table 4.

It is of interest to note the wide variability in the reaction-times of persons of the same age. For example: of those 19 years of age, the longest reaction-time is 0.74, and the shortest, 0.43 sec. In other words, the reaction-time of one person is almost twice as long as that of the other. These results may be generalized by saying that practically no relation seems to exist between the reaction-time and the age of the individual. The age limit of 44 years may not have been sufficiently high to show such differences as may exist at more advanced age. It is possible, also, that the element of training tends to offset whatever lengthening there may be in the reaction-time of a person because of increasing age.

Sex

Judging from popular opinion, the reaction-times of women might be expected to be radically different from those of men. The experiments fail to substantiate this belief. The average reaction-time of the 10 college women is 0.56 sec., while that of the 25 college men from the same institution is 0.59 sec. Women have also been accused of being more variable than men; and the data are of interest in throwing light on this matter. The mean variability of the 10 women students of George Washington University is 0.17 sec., while that of the 25 men students is 0.22 sec. The number of cases, of course, is not sufficiently large to warrant sweeping conclusions.

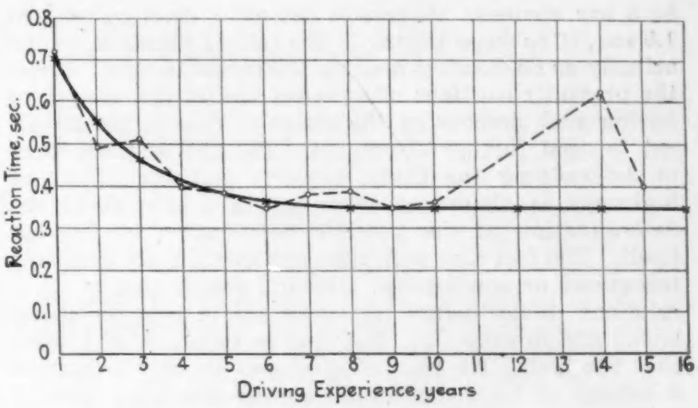

FIG. 5—EFFECT OF TRAINING ON PERFORMANCE
This Graph Enables a Prediction To Be Made as to the Performance of a Person after a Given Number of Years of Experience

Too few persons were tested to draw definite conclusions as to the effect of race on reaction-time.

General Intelligence

Many investigators have found a close relation between reaction-time and general intelligence, as measured by current standardized intelligence tests. In the case of the George Washington University students for whom Army Alpha scores were available, a correlation was prepared that shows the relation between reaction-time and general intelligence. An inverse relation between these two variables was secured. In other words, persons having high intelligence-scores seemed to have a marked tendency toward short reaction-times. A similar relation, found between general intelligence and variability, would seem to indicate that, contrary to the popular conception, persons having the highest intelligence tend to be the least variable in their reaction-times. Unfortunately, Army Alpha scores could be secured for only 24 of the persons tested, which obviously is too small a number on which to base final conclusions.

Application of the Results

The practical use of findings of this kind is of interest. In the licensing of automobile drivers, definite norms might be worked out giving reaction-times, the exceeding of which would prohibit an applicant from receiving a driver's license. The reasons for requirements of this

TABLE 4—VARIABILITY OF REACTION-TIME WITH AGE

Age	Reaction-Time, Sec.	Average for This Age, Sec.
16	0.68	0.68
17	0.54	0.54
18	0.67, 0.74, 0.75	0.72
19	0.43, 0.49, 0.60, 0.63, 0.74	0.58
20	0.44, 0.45, 0.48, 0.55, 0.55, 0.56, 0.58, 0.59, 0.88	0.56

Age, Years	Reaction-Time, Sec.	Average for This Age, Sec.
21	0.24, 0.45, 0.47, 0.47, 0.50, 0.57	0.48
22	0.32, 0.38, 0.47, 0.64	0.45
23	0.34, 0.39, 0.46, 0.46, 0.48, 0.50, 0.55, 0.63, 0.93	0.53

Age, Years	Reaction-Time, Sec.	Average for This Age, Sec.
24	0.38, 0.42, 0.46, 0.52, 0.63, 1.01	0.57
25	0.38, 0.40, 0.61	0.34
26	0.48	0.48
27	0.38, 0.51, 0.52	0.47
28	0.31	0.31
31	0.46, 0.75	0.61
32	0.55	0.55
33	0.50	0.50
44	0.65	0.65

kind are obvious. A person having a reaction-time of 1.5 sec., if he were driving at the rate of 30 m.p.h., would actually go 66 ft. after hearing the signal to stop. Under the present conditions of crowded traffic, the danger of having such persons on the street or road is too apparent to need further discussion. The use of these tests in determining the traffic capacity and the utility of highways is almost as important a factor as is the determination of the possible deceleration of the car itself. The fact that such relations exist, is not generally recognized or appreciated. General recognition of these relations would ensure increased safety both to pedestrians and to property. It would be expected, of course, that the tests for reaction-time can be only a part of a battery of tests that would include the usual ones of performance given to automobile operators.

SUMMARY

The results of these experiments may be summarized as follows:

(1) The average reaction-time of the persons tested is approximately ½ sec.

(2) A marked relation was found between reaction-time and mean variability

(3) The reaction-time is not appreciably affected by the speed at which the person is driving

(4) The reaction-time may be reduced by training; the reduction, however, in some cases must of necessity stop far short of that in others

(5) Little relation seems to exist between the reaction-time and the age of the person tested

(6) The factor of sex is shown to have little effect upon the reaction-time

(7) Insufficient data are at hand to determine the effect of race on reaction-time

(8) A marked relation was found between general intelligence and reaction-time

Acknowledgment is made to B. L. Weikert, of the Bureau of Standards, who assisted both in the mechanical equipment and in conducting the tests; and to Dr. William Mather Lewis, president of George Washington University, Dr. J. Stanley Durkee, president of Howard University, and the Black & White Taxicab Co. for their cooperation in furnishing personnel for the tests.

CHINA'S FOREIGN TRADE

WITH constantly recurring civil wars, government succeeding government, rampant political confusion, unwieldy moving armies belonging to the various provincial leaders forcing themselves upon the towns and villages, compulsory military labor and wholesale brigandage which the authorities cannot or will not suppress, the sum-total of China's foreign trade, as revealed by the official returns of exports and imports, holds up well from year to year. That trade is sustained is due, as a rule, to the fact that civil disturbances are sporadic, not national. They customarily occur, at different periods, in widely separated areas or limited districts; and while one district may be suffering from a huge loss in purchasing power, another may be highly prosperous until such time as the fortunes of internecine warfare reverse the situation between them.

Even allowing for this ameliorating condition, however, it may be assumed that if China's foreign and export trade is fairly good in the existing circumstances, the volume is as nothing compared to what it might be were the country stabilized, political chaos ended and finis written to the volume of inter-provincial unrest and discord that has marked China's history since the Republic was founded.

The British and the Japanese have a keen realization of trade possibilities with China, and unquestionably enjoy more of it than the nationals of any other two countries. Many big American firms are too quickly overtaxed in patience. The Germans, now that they are again established in China, are quietly but effectively working to regain that commercial prestige which was so abruptly lost when China entered the World War on the side of the Allies. The Russians are today busy throughout China and have been since China recognized Soviet Russia on May 31, 1924. But Russia, for the moment, comes more as a buyer than as a seller.

Japan understands China better than any other nation, because of her proximity, and holds an ascendency in trade with China, not because of any superiority of goods, but because she has capitalized that understanding. Britain and Germany are capitalizing their knowledge of colonization. American goods are by far the most popular of foreign wares among the Chinese. Yet the Chinese, themselves models of patience, find it difficult to understand the impatience of many American business men who come to China to trade and expect to do so before familiarizing themselves with Chinese customs.—*Mercantile Trust Review of the Pacific.*

GEAR TESTS AT THE NATIONAL PHYSICAL LABORATORY

IN a test recently made at the National Physical Laboratory on a Maag spur gear, the spacing and pitch errors of both sets of tooth faces were measured as was also the error in the form of the profile. The circular-pitch error in no case exceeded 0.002 in. and in about two-thirds of the cases was less than 0.0001 in. The eccentricity error also did not exceed the latter limit and the report states that "as regards the location of the teeth this gear reaches a high degree of precision in all respects." The errors in the form of the profile in no case exceeded 0.0001 in. and, in fact, the report states that these errors in form were comparable with the possible errors of observation. The error in parallelism between the axis of a tooth and the axis of the wheel was found to be less than 0.0001 in. in the full length of the tooth.

In view of the high accuracy thus proved to be attained in the manufacture of these gears, the maker, Sulzer Bros., Winterthur, Switzerland, suggests that it would be well if the delicacy of the testing instruments could be increased. The teeth of these gears are finished by grinding, the operation being effected by two saucer-shaped discs that grind on the edge only. The actual cutting surface lies, therefore, wholly in a plane, and thus a true involute form must be given to the tooth, if the proper relative motion is given to the gear operated on. To compensate for wear a device is fitted which acts every few seconds, and insures that the proper relative position of the disc is never in error by more than 0.0001 mm. (0.000039 in.). It is thus possible to grind gears of any desired face width, and this firm has already supplied ground gears with a face width of 900 mm. (35.44 in.).—*Engineering* (London).

Pneumatic-Tire Elements and Development[1]

By L. J. D. HEALY[2]

ABSTRACT

RUBBER, so-called from its first function of removing pencil marks, is obtained from trees in a manner similar to that of gathering maple sap. The various steps in the process of transforming this sap into material suitable for use in automobile tires are described in detail. These include coagulating, pressing, drying, molding, compounding and vulcanizing. From the bead up, fabric, cord and balloon tires are practically the same. The beads are of two types, (*a*) the straight-side and (*b*) the clincher. Cotton fibers vary in length from the first Egyptian uppers, 1½ in. long, to the American, the staple of which is 1⅛ in. long. The tiny fibers of the cotton, which are about 1/2000 in. in diameter, are formed by successive twistings into cables, which, in turn, are woven into fabrics, the common or square-woven type differing from the cord type in the manner of weaving. The fabrics are then processed with rubber in such a way that each layer or ply can work harmoniously under the bendings of the tire that are incidental to service. The rubber layer surrounding the threads and termed the friction coat has the double function of holding the threads together and of keeping them apart, for if they rub one against another, heat is produced, the fabric carbonizes and the carcass disintegrates. Because of the fact that the fibers of the cord tire run parallel rather than overlap, as in the fabric tire, flexing action is less injurious to the cord tire than to the fabric tire. Different sizes and types of tire are distinguished by colors, so that the proper kinds of fabric will be used in their construction. The special requirements of breaker, side-wall and tread stocks are explained, and the process of constructing a tire by a tire-building machine are outlined. As a final step the tires are sent to the vulcanizer, in which they are molded by hydraulic pressure into the proper shape and are impressed with the customary lettering and marking.

The gradual increase in the cross-sectional area of tires reached a point at which an excessive amount of weight was added to the unsprung portion of the car and complications due to fitting and maintenance increased. To meet the demand for lighter cars and at the same time provide proper cushioning against road shocks, the balloon tire was evolved. This is nothing more nor less than a lightweight cord tire of large air-volume. With lower air-pressure so heavy a carcass is not required, fewer plies of cord are needed, a more flexible carcass can be applied, and this, in turn, gives a much greater yielding periphery of the wheel, with the result that vibrations and shocks are absorbed more effectively. Balloon tires are said to possess practically the same durability as high-pressure tires, with the exception that the wear of the tread is greater. Wear is said to be greater on rear than on front balloon-tires, and to be the greatest on the outside edge of the tread of front wheels and on the inside edge of rear wheels.

The conclusion is that, following the trend of car design in the effort to reduce the unsprung weight, future development will lie along the line of the balloon tire. Rearrangement of the braking system is important. The development of the ultimate comfortable high-speed economical lightweight car will require the combined efforts of the automobile engineer, the spring engineer and the tire engineer.

RUBBER originally derived its name from the fact that the English chemist Priestly discovered that it could be used in rubbing out pencil marks. It is obtained in the form of milk or latex from trees of the Hevea species, which thrive in tropical and intertropical zones. The milk is secreted in the intercellular veins in the interior of the bark. When the tree is tapped or gashed with a sharp instrument, the milk flows freely and is caught in tin cups, after which it is carried to the rubber factory to be either coagulated into rubber gum or transferred to tank cars.

At the factory, coagulation is produced by spraying the milk and drying off the water, or by pouring it into large vats and stirring, usually with the addition of a small amount of salt or acid. Rubber coagulates in a manner similar to that of butter fat in ordinary cows' milk, separating itself from the water and floating at the top. After the water has been drained off, the curd is pressed into sheets by being rolled between rollers, and is then hung up or laid in trays to dry; this is the form in which the tire manufacturer receives the rubber for building tires.

Rubber is a colloidal substance having an approximate formula of 10 parts of carbon combined with 16 parts of hydrogen. It has physical and chemical properties that are of great importance, so far as the tire industry is concerned; but one particular chemical property is of outstanding interest, namely, the property of combining with sulphur to form so-called vulcanized rubber.

The rubber tree is tapped in much the same way that a maple tree is tapped for maple syrup, except that the gashes are deeper. The rubber latex flows out. The tapping usually takes place in the morning; by midday, the rubber, coagulating more or less by the heat of the sun, clogs up the cut and the running of sap stops. The next day, the gashes are opened again and more sap is obtained. It is a limpid liquid of about the color and consistency of ordinary milk. The liquid is an emulsion. About 35 per cent of it is rubber, 2 or 3 per cent is impurities, such as certain sugars and resins, and the rest is water.

SMOKED RIBBED SHEET AND PALE CREPE RUBBER

The only difference between the smoked ribbed sheet and the white crepe sheet is that the smoked sheet is dried in a smoky atmosphere and is called a smoked sheet; the white crepe sheet has been dried without smoke and is usually called first latex or pale crepe. The crepe sheet is usually used when a white-colored stock, like the white side-wall of a tire or tread, is wanted; the smoked sheet can be used for that purpose also when color is of minor importance. Developing the white color

[1] From a paper presented at a joint session of the Milwaukee and the Chicago Sections.

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requires the addition of white coloring matter, such as zinc oxide or lithopone. There is practically no difference in the general purposes for which either kind of rubber can be used. Some persons prefer the smoked sheet, thinking it is mellower; others prefer the first latex. The first latex makes a slightly firmer harder stock, but the two kinds are interchangeable in tire work.

In its raw state, rubber has a specific gravity of 0.93, is transparent in thin sheets, and has considerable elasticity and pliability. When gently heated and masticated, it gradually attains a more doughy highly-plastic state and can be molded or pressed into any desired shape. While in this state, it can be chemically compounded with sulphur, after which it assumes entirely new physical properties, being no longer soluble in the ordinary solvents, such as turpentine, naphtha, and the like, nor influenced by ordinary heat or cold. Furthermore, and yet more important, it is no longer tacky, but its strength and elasticity have been greatly increased and it retains a permanent consistency. This is the process of vulcanization discovered by Charles Goodyear of New Haven, Conn.

While in the plastic state and before being vulcanized, rubber can be compounded with various chemicals, ingredients and coloring matters and may be pressed into fabrics or extruded and molded into any desired shape. Having thus been shaped, it can be subjected to heat, after which it retains, as a permanent form, the shape into which it was molded.

Action of Sulphur

The sulphur that produces the chemical reaction is nothing more or less than the common powdered sulphur so commonly used for medicinal purposes. The sulphur is ground extremely fine; in fact, as fine as it is possible to grind it commercially.

Another important filling material for tires is zinc oxide, which is used for making white-tread tires and white side-walls and also, in conjunction with carbon black, for making black treads. Carbon black is very finely divided gas black, made from natural gas, and is probably the finest and greatest reinforcing agent that can be put into rubber. Sulphur is absolutely essential to bring about the chemical reaction; carbon is added to give strength and wearing quality to tread stocks.

The conditions under which tires are used vary so widely, and the abuse to which they are subjected is so great, that a very high factor of safety must be provided to insure that they can withstand this rough usage with safety and durability. It might be of interest to note that the factor of safety of an average tire is from 8 to 10 times the strength required to withstand the normal bursting-pressure. All tires contain the following component parts: the beads, the carcass or fabric structure, the cushion, the breaker, the tread and the side-walls.

Beads

From the beads up, tires are made practically the same. The bead is the part of the tire that comes into immediate contact with the rim and serves to anchor the tire in place. Beads are of two common types, (*a*) the clincher and (*b*) the straight-side. The clincher bead is used only on small-sized tires and is flexible, so that it can stretch over the edge of the rim. The outer edges hook under the rim flange and are held in place by the air-pressure.

The straight-side bead, on the other hand, is non-extensible, being composed of a series of wire cables. There is danger of a clincher tire coming off the rim, if it goes flat but, in the case of the straight-side tire, there is not this danger, since the bead is composed of non-stretchable wire that cannot stretch over the rim flanges.

The clincher bead is made by extruding rubber through a tubing-machine, such that the general cross-section will fit the clinch of the rim. This is then molded to the exact size ready for the tire-builder. The bead stock extrudes from the tubing-machine in circular form, coming out about the size of one's little finger. It then goes into a mold and is shaped into the exact size of the clinch.

The straight-side bead is composed of either a number of steel cables or a number of plies of braided steel wire, which are passed through a machine and are coated with a hard rubber composition. The cables, or wires, are then removed, more rubber and fabric are added and the beads are molded into their proper shapes under an hydraulic pressure of about 2000 lb. per sq. in. This operation takes about 5 min., during which the rubber and the fabric vulcanize to the consistency of hard ebonite and completely surround the wires. An additional amount of rubber fabric is squeezed around the wires and is put into the mold, which has the same general cross-section as the triangular piece of stock; the rubber fabric is pressed under high pressure for 5 min., after which it comes out very hard and in a more or less inelastic condition, making a solid hard anchorage for the base of the tire. When the tire receives its final vulcanization, it becomes still harder, and, by the time the tire is complete, the bead is practically ebonized, with the fabric and the wire imbedded in it.

Carcass or Fabric Structure

The carcass or fabric structure is the backbone of the tire. Two basic types of fabric are used, namely, the so-called square-woven fabric and the cord fabric. Both these types are made from cotton yarns, in which several different grades of cotton are used. The first, Egyptian upper, or Sacalaretes, is a long-staple cotton, the fiber of which is about 1½ in. in length; the second is Egyptian cotton, the staple or fiber of which is about 1-3/16 in. long; and the third is American cotton, which has a staple about 1⅛ in. in length. These fibers are so small in diameter that it would take about 2000 of them lying side by side to measure 1 in.

A so-called Sea Island cotton, very similar in quality to the best Egyptian cotton, is also produced in this Country, but this cotton is no longer on the market owing to the ravages of the boll-weevil. Tiny as the fibers are, when properly spun together, they make an extremely strong yarn. After the fibers have passed through a machine that combs out all the seeds, foreign matter and also the very short fibers, the combed fibers are twisted together in a spinning-machine to make a so-called yarn. The weight of this yarn is dependent upon the number of fibers and twists that make up a certain length; consequently, yarns are known by their number or weight. The yarns are then twisted together to form a cable, and the cables, in turn, are twisted together to form a still larger cable or cord. These cords are then used in the looms for weaving the tire fabrics. It may be of interest to note that a 5-in. tire contains more than 5700 miles of fiber. It is the proper choice of these fibers that gives the tire fabric its strength and service.

Cord Tires

Cord tires are made of cords or threads that run in one direction but are held together loosely by small cross threads. The cords are called the warp; the cross

threads, the filler. The filler threads are extremely light and just strong enough to hold the cords parallel. Usually there are about 24 cords to the inch in the warp, whereas there are only two or three very light filler threads to the inch.

Fabric tires are made from the common square-woven fabric, the threads of which are of equal size, some running one way, some the other, being interwoven. The cord fabric, on the other hand, consists of a series of cords lying parallel and held together with very fine cross threads. The thread is put in merely to hold the cords together. If it were not there, the cords would separate just as they do when the threads are broken. The threads hold the cords parallel during the process of applying the rubber and serve no purpose except that of holding the fabric so that it can be processed with the rubber. These two fabrics make the difference between the cord and the fabric tires.

Tire fabrics must be processed with rubber in such a way that each layer or ply can work harmoniously under the bendings of the tire that are incidental to service. When a 32 x 4-in. cord tire is inflated to an air-pressure of 60 lb. per sq. in., an outward force of 30 tons is exerted within it. When loaded to 1200 lb. it is pressed in nearly $\frac{3}{4}$ in. and when the wheel revolves each part of the tire is deflected by that amount. It is constantly bent back and forth in service. Wire bent in this way quickly breaks, but the fabric in a tire bends more than 6,000,000 times in 10,000 miles.

The tire service has increased remarkably in the last 5 years because of the scientific adjustment of the threads that compose the fabric and the cord, as well as of the greater resistance of the rubber layers to flexure and heat. In extreme flexing and rapid motion, the fabric of an automobile tire becomes heated. It is absolutely necessary that each thread of cotton be insulated from every other, so far as possible, to prevent friction and heat, for two threads seesawing against each other soon become heated, the fiber becomes carbonized, and the carcass disintegrates very rapidly.

The Friction Coat

The rubber layer that surrounds the threads and separates the plies is called the friction coat; besides holding the plies together, it at the same time keeps them apart so that they cannot rub against one another. This rubber must serve as a permanent lubricant, not temporary like oil. No other substance yet found will remain so permanent, under heat and bending, as will vulcanized rubber. Rubber is frictioned and coated on tire fabrics by running the fabrics between the rolls of large calenders; during the operation of frictioning the rubber is forced completely around the cotton threads of the fabric, which then passes through another calender that coats both sides of the fabric with more rubber.

The fabric is now in condition to be built into the tire. It is impossible, during the frictioning and coating operations, to surround the cords of the square-woven fabric as thoroughly as those of the cord fabric. Owing to the interlocking nature of the square-woven fabric, the threads wear against one another during flexion on the road and consequently give a shorter mileage than does the cord tire. In the cord fabric, the warp threads straighten out into approximately parallel lines during these operations, and none of the cords is in contact with its adjacent partner.

Each cord, or layer of cords, is separated from every other cord or layer by rubber, whereas, in the fabric, each thread overlaps the one adjacent to it. These are the fundamental differences between cord and fabric tires, and explain why the continued flexing action is less injurious to the cord tire than to the fabric tire. This, in fact, is the primary reason that the cord tire is more flexible, has a lesser tendency to become injured, and gives greater mileage.

Coloring of Tires

Different sizes and types of tire are colored so that the different types or particular tires in which they are to go can be distinguished. Some tires differ from others slightly in construction, and thus, if the rubber were not colored, one fabric might easily be mistaken for another.

Breaker

In addition to the carcass fabric, a tire also contains a strip of so-called breaker fabric. This is a peculiar open-weave construction and, when placed above the dome of the carcass, serves as a buffer from road shocks, preventing undue injury to the carcass fabric underneath. Between this breaker fabric and the carcass fabric is inserted a strip of very soft and resilient rubber called the "cushion," or padding. This serves as a further cushion to the carcass fabric or cords against the hard blows received on the road.

Surrounding the carcass structure are the tread and the side-wall stocks. These serve as a protective covering for the fabric. Thus, consisting of a tough composition of rubber and other chemical ingredients that has been evolved after painstaking and intricate study on the part of chemists, the tread is a highly resilient and, at the same time, an extremely wear-resisting rubber mixture. When tested in an abrasion machine, a good tire-tread has been found to outwear dry leather about $2\frac{1}{2}$ times, wet leather more than 10 times; and it will resist the action of a powerful sand-blast 3 times as long as will iron. It is, therefore, the material most resistant to road abrasion that the chemist has been able to produce.

The Side Wall

Similar to the tread stock is the side-wall stock, the main difference being that the latter is usually slightly less resistant to wear but more elastic and flexible, since it is placed at that portion of the tire that gets the greatest flexing action. Tests have proved that rubber of highly elastic composition is somewhat better for this portion of the tire than is the stiffer tread-stock.

The treads are formed by passing the rubber through a tubing-machine and squirting it through a die in the right thickness and width. As the tread rubber is squirted from the tubing-machine, it is carried by conveyor belts through tanks of water in which it is cooled and shrunk. The side-wall stock is sheeted out through calender rolls to the correct width and gage.

The various parts of the tire, after having been prepared, are carried on conveyors to the tire-building machines on which they are assembled into the complete tire. A tire-building machine consists essentially of a revolving arbor carrying a core or former of the correct cross-sectional area for shaping the tire. The machine also contains certain attachments for applying the rubber to the core. The movement of the core and of all these attachments is controlled by the operator through pedals or levers. In other words, it is nothing more nor less than an arbor with arms for attaching the core, which is an iron casting, usually hollow, of the same cross-sectional shape as the tire that is to be built upon it, and is turned in a vertical plane by an electric motor. The machine is comparatively small; it would not take up

more room than an ordinary table, if as much, and contains all the tools, stitchers, knives and paraphernalia for trimming, cutting and rolling the tire into shape on the core. The core is made so that it can be collapsed after the tire has been built on it, and is of the same size as the inside of the tire casing; consequently, a separate core is required for each size and type of tire.

When an operator takes from the conveyor the fabric, which has been prepared in the cutting-room in the right lengths and widths for the particular size of tire that he is to build, he shapes it around the core and stitches it down with small mechanically operated rollers called stitchers. About one-half the number of plies of fabric or cord are placed on the core and the beads are inserted at the base. When these have been rolled into place and firmly held by stitching the lower edges of the cords around the bead, the remaining half of the plies are formed and stitched around the core and over the first plies. This operation finishes the carcass or fabric portion of the tire.

Tread Assembly

The tread assembly, which has been prepared in the tread-building department, consists of the breaker, the cushion and the tread stock, which have been rolled into one unit. This is applied by the tire-builder to the outer portion of the carcass and is rolled down by pressure rollers.

The side walls, which have been prepared in the side-wall department, are taken from the conveyor and rolled into place in a manner similar to that in which the tread was applied. All parts of the tire are then carefully stitched down with mechanical stitchers and the tire is complete, ready for vulcanizing. The operator then collapses the core, removes the tire, and places it on a conveyor, which takes it to the vulcanizing department. On its way, an air or water bag is inserted within it. The tire then proceeds to the vulcanizer.

A vulcanizer consists of a large steel chamber, with an hydraulic-ram for raising or lowering the platform upon which the tire molds are placed. The molds are two-part steel castings, designed so that they have exactly the same exterior shape that the tires are to have when finished, including all the lettering and other markings. As the tire travels along the conveyor, it meets one of these molds, which has just discharged a finished tire. The upper half of the mold travels along the conveyor at some distance above the lower half. The tire drops into the lower half of the mold and the upper half automatically drops into place. The molds then proceed along the conveyor to the vulcanizer, and slide in, one above the other, as the hydraulic-ram of the vulcanizer is lowered slowly to make room for a succeeding mold.

As soon as the molds slip into the vulcanizer, air connections are made between the air-bag and the proper air-lines. After the vulcanizer has been filled, the cover is dropped into place and securely bolted. Hydraulic pressure is applied and air is forced into the tires at the proper pressure. The air expands the air-bag, which, in turn, expands the tire and drives it against the mold. Immediately after the air-pressure has been turned on, steam is admitted to the vulcanizer, producing the chemical action known as vulcanization. After remaining in the vulcanizer for the proper length of time, the mold is removed and slid out of the vulcanizer onto the conveyor. At a certain point in the conveyor system, the top half is lifted automatically and the vulcanized tire is removed from the mold and transferred to another conveyor, which takes it to the department where the air-bags are removed. After the air-bags have been inspected, they are sent back on another conveyor to be placed in other tires. The tire is then carried by a conveyor to the inspection room, where it is carefully inspected for blemishes or defects, is coated on the inside with mica paint to prevent the inner tube from sticking to the tire, is wrapped and sent to the finished goods department.

Automobile designers have been gradually specifying larger cross-sectional sizes of tire, in order that the riding-comfort might be improved. A point was finally reached at which the wheel and the rim equipment began to add an excessive amount of weight to the unsprung portion of the car; the cost of the rim and flap equipment also increased, to say nothing of the complications due to fitting and maintenance. The natural trend toward making cars lighter and more economical made it necessary to provide the cars with tires that are lighter but of sufficient size to provide proper cushioning against road shocks. The balloon tire was evolved to fill this need.

Balloon Tires

A balloon tire is nothing more nor less than a light-weight cord tire of large air-volume. Instead of the usual volume of air at high pressure, we have a greater volume at lower pressure. With lower air-pressure so heavy a carcass is not required to withstand the strain, fewer plies of cord are needed, a more flexible carcass can be applied, and this, in turn, gives a much-greater-yielding periphery of the wheel. In consequence, vibrations and shocks are absorbed to a greater degree than they are by the stiffer-walled high-pressure tire.

If a stiff-walled tire goes over an obstruction, very little indentation of the tire occurs; the whole weight of the car is lifted and the tire is indented only slightly. After it has passed over an obstruction, the car jolts down again to the road level, and a jar and a vibration are set up that are transmitted to the car-springs and the body. When a balloon tire goes over an obstruction, it swallows up the obstruction, the whole carcass deflects, and no effect is produced on the rim, the wheel and the parts of the car. The cushioning effect is very pronounced.

Balloon tires have been used on our fleet of eight test-cars, and have given consistently good service with very little trouble from punctures and blowouts. In fact, I think I can truthfully say that the service is almost equivalent to that of the regular high-pressure tire. Some persons have claimed that more punctures have occurred with balloon tires, but our experience has not shown that to be the case under the road conditions of Wisconsin, northern Illinois and eastern Iowa. The carcass is somewhat thinner, so that a tack of a certain size might go through the tire, especially at the sides; but punctures from small tacks are few and far between; on the whole, balloon tires have given practically the same durability as do higher-pressure tires.

Wear of Tread

One exception to this statement is the fact that the tread wear is greater, but we believe this can be overcome by proper design and proper distribution of the tread stock. Naturally, in going over obstructions in the road, there is a more or less side swiping action, in addition to the increased tractive resistance that wears the tread of a balloon tire at a faster rate than that of a high-pressure tire. We believe that we can overcome this wear by the proper distribution of the rubber, but it has not been absolutely overcome as yet. The efficiency of a balloon tire is about the same as that of a high-

pressure cord tire when used with a somewhat reduced air-pressure. The rolling resistance is slightly greater than that of high-pressure tires inflated with their correct pressure.

We have a man who makes a systematic check of the tire-pressures usually carried, when the cars stand parked in parking stations and similar places. We have found that within the last few years there has been a decided tendency to reduce the pressure in some cord tires, in fact, some of the pressures that are carried are almost ridiculous; the cars must almost hit the rim when they go over an obstruction. When the tires are in that condition, they are no more efficient than are balloon tires at the air-pressure that should be used, which is much lower than that of high-pressure tires. No difference exists between balloon and high-pressure tires in the ease of replacement, for this factor is largely a matter of rim design.

When balloon tires are used on the front wheels, the wear seems to be the greatest on the outside edge of the tread; on the rear wheels, it appears to be the greatest on the inside edge. The former is due to the pitch and toe-in of the wheels, the latter to the slope of the road-bed. Although the wear on the rear wheels is greater than on the front wheels, off-center wear, nevertheless, is more pronounced on the front than on the rear wheels. A wheel with a soft tire tends to take this position, bearing a little more to the side of the center. The front wheels, because of their pulling action, seem to have a greater tendency to wear in that way, as has often been shown on ordinary high-pressure tires. The tread could probably be distributed so that the wear would approximately be equalized.

Future Development

The tire of the future will probably be developed along the lines of the balloon tire; it will be flexible, of generous proportions, and as light as possible, consistently with strength and durability. Furthermore, it will be adapted to a lightweight rim. Its development naturally will follow the trend of car design. The trend of automobile design will, no doubt, be along the lines of reduced unsprung weight. This will allow lighter tires, rims and wheel construction and will result in better riding-quality. It goes without saying that the less the weight is under the springs, the better it will be for the tires and for the occupants of the car. As you all know they are working along this line in Europe. To reduce the unsprung weight, the brakes are taken off the wheels and are put on the transmission, because the high price of gasoline and the smaller purchasing power of their money necessitate the use of highly efficient cars of very light weight. This means that extremely light wheels and a short wheelbase must be used to obtain the comfort that we get in this Country with heavier cars, in which the ratio of the sprung to the unsprung weight is not of so great consequence. Removal of the brakes from the wheels to the sprung portion of the chassis, together with lighter axles and wheels, will allow the use of lighter and more flexible tires. This, in turn, should give added comfort, durability and efficiency. Thus, the automobile engineer, the spring engineer and the tire engineer, working in unison, will, no doubt, some day evolve the long-looked for comfortable high speed economical lightweight car.

THE DISCUSSION

QUESTION:—How does a truck tire differ from a regular pneumatic tire?

L. J. D. HEALY:—A truck pneumatic-tire is practically an enlarged cord tire. The only difference is that more rubber is used between the cords. The cords are sometimes constructed somewhat differently, but many truck tires are made of exactly the same cords as those used in passenger-car balloon cord-tires. The only difference usually is that the coat of rubber between the plies of the cord is increased somewhat and the cushion construction above the carcass is heavier. Outside of that they are absolutely identical.

R. S. PFEIFFER:—Is the size of the cord proportionate to the size of the tire?

MR. HEALY:—It is not. The same size of cord is generally used for all sizes of tire. The only thing that varies is the number of plies.

MR. PFEIFFER:—Is it always necessary to use an even number of plies to tie the cords together?

MR. HEALY:—It makes the best balanced tire. Many tires on the market have an uneven number of plies, but this is done largely with the idea of lessening the sales resistance and of making the carcass look a little heavier in cross-section. The ideal type of tire should have the same number of plies in each direction. It is possible to make a tire of, say, two plies of cord that are very large, almost approximating to a small cable or clothes line, if you wish to call it that, as against a great many plies of smaller cords. I think it has been proved absolutely that a tire made of many small-size cords will last longer and give more consistent results than will one made of fewer plies of thick cords, because the larger the cord, the more difficult it is to get the rubber between the individual strands, and more frictional heat is generated in the cord itself; if a great many cords of small diameter are used, very little frictional heat is generated within the cord itself, because it is soft and flexible and each individual cord is separated from the others by a film of rubber that prevents them from rubbing together. The generation of frictional heat; consequently is reduced.

D. M. AVERILL:—Has the two-cured tire any advantage over the single-cured tire?

MR. HEALY:—The single-cured tire as it is made today, is the tire generally adopted. Very few two-cured tires are made because of the expense and the fact that they do not give any better service than does a single-cured tire. In the double-cured tire the carcass portion is molded separately. Usually it is molded on an iron form without an air-bag. The tread is not put on in that operation because, when a rigid iron core is used, the tolerance has to be so fine that it is impossible to design the tread portion and mold it without throwing the cords out of line and making buckles and wrinkles. To overcome that difficulty the carcass is molded separately and is given about half a cure, which is enough to set it to semi-hardness. When the soft rubber has been put on the outside of the tire, an air-bag is inserted, a tread, with the design on it, is put into place, and the two are vulcanized together a second time, to unite the tread and the carcass portions. In other words, the tread is molded separately from the carcass during the semi-cure and, during the final or second cure, the two are vulcanized together.

MR. AVERILL:—Is there any value in the argument that second-cured tires can be made better or more perfectly because it is possible to inspect the main carcass before the tread has been applied.

MR. HEALY:—That may be a good selling argument. The first tires that we made were all two-cured simply because we did not know how to make a good single-cured tire. Today, the development of the tire has been

such that the single-cured is considered better than the double-cured tire, because the tread can be put on and vulcanized in one solid unit, whereas, with the two-cured tire, an element of danger always exists between the unions. In other words, the unions would not unite perfectly as they do with the single-cured tire.

MR. AVERILL:— Does the size of tire make any difference in the method of cure?

MR. HEALY:—No.

MR. AVERILL:—Is there such a thing among tire manufacturers as having a standard number of plies on the same size of tire?

MR. HEALY:—It is customary among the different makes of tire on the market that tires of a certain size shall have the same number of plies. Tire competition has been so keen within the last few years that a great many different styles and types of tire have been made. One type of tire has been made for the jobber, another for standard quality, and still another without a guarantee. The quality of some tires has been cheapened in many ways, especially when the tires have not been guaranteed.

MR. AVERILL:—One of the things that we have had to contend with, in this multiplicity of changes that have been made in balloon tires, in sizes, standardization, and the like, in the last few months, is the fact that practically every tire manufacturer has two grades of tire. One he sells to the dealer, the other to the manufacturer.

MR. HEALY:—Manufacturers often ask for certain tires at certain prices. It is a common practice among certain manufacturers to say, "We want a tire of a certain size, so many plies, to sell at such a price." The tire company makes the tire according to those specifications. It is largely done to reduce the sales resistance.

Rubber today is selling for only 25 cents per lb., whereas 14 years ago it sold for $2.50 to $3.00. Today, the plantations are so enormous in size that the supply of rubber is almost greater than the consumption. Adulterating it would have little object. The cheaper grades of tire usually contain some reclaimed rubber and usually a cheaper fabric. The easiest way to reduce the quality of a tire is to reduce the number of plies, or use a lower quality of cotton. But if you do not use quality there, you do not have anything.

QUESTION:—Has the drop-base rim any advantage?

MR. HEALY:—The drop-base rim has some very good features. In this country, everybody is accustomed to the demountable rim and the drop-base tire does not adapt itself to that type of rim; but it would be very adaptable to a steel wheel or a wire wheel.

QUESTION:—How was the cross-sectional size of the balloon tire determined?

MR. HEALY: — The balloon tire has the same cross-sectional sizes as has the 10-per cent-oversize standard cord-tire. There is absolutely no basis for it. It is simply a standard that was adopted years ago and has continued. It means nothing except that the tire was made of that size.

LOW-TEMPERATURE CARBONIZATION OF COAL

THE forests that have been fossilized to produce coal appear to have contained trees with the same sort of variety in their chemical composition as can be found in growing trees today, and the fossilizing process has left the coal with variations as great. It has, therefore, been necessary, not for the purpose of using coal, but of carbonizing it, to inquire much more closely into its composition. Until comparatively recent years this inquiry has been limited to proximate analyses, which determine the proportions of moisture, volatile matter, fixed carbon and ash; ultimate analyses, which specify the proportions in which the constituent elements are found; and determinations of calorific value; with later on a determination of the "coking index," measuring the amount of sand that can be mixed with a fine-ground coal before carbonization, to produce a coke of a standard strength.

All these determinations, except that of calorific value, though perhaps better than nothing, were under the disadvantage that they were merely conventional, and did not correspond to the properties that actually affected both carbonization and the subsequent use of the products. It was found accordingly that for judging the suitability of a given coal for such a purpose as low-temperature carbonization it was necessary to have some method of assay that would reveal its behavior in the temperatures to which it was to be subjected. Methods such as those of Gray and King and of Lessing were accordingly evolved, and threw considerable light on the behavior of different coals; and by his judicious, patient, and skillful microscopical work Beilby showed how the properties of a blend of coals, neither of which would be suitable by itself for carbonization at low temperatures, might be made thoroughly satisfactory. All this work has amounted to a considerable advance; but the processes of carbonization to be practised on such heterogeneous materials have been found to raise an infinity of problems, which at the present time are being attacked vigorously and systematically, but so far have yielded no final practical solution.

That all this work should have been done is due to a realization, not confined to technical men, that if a way could be found of carbonizing coal at low temperatures economically and with practical convenience, it might be a means of abolishing the wasteful and mischievous nuisance of smoke, and of providing within the country a supply of fuel oil and perhaps also internal-combustion engine fuel. Between the wish to attain these results and the elaboration of the means there has proved to be a wide distance, and the lay world is waiting with more or less impatience until some practical means shall have been demonstrated. In such temperatures it is plain that any works which deal from a practical point of view with the subject of low-temperature carbonization must be in the nature of interim reports, and their value will be greater insofar as they enable the reader to master separately the main considerations that enter into the problem in each of its many different aspects.—*Engineering* (London).

Six-Wheel Truck Construction and Operation

By Ethelbert Favary[1]

Los Angeles Group Paper *Illustrated with* Drawings and Photographs

ABSTRACT

BENEFITS gained by distributing truck weights and loads among six wheels rather than four, include less liability to cause road destruction, greater carrying capacity and more economical operation. The author classifies the causes of road destruction under headings of excessive loads on tires, impacts between road and tires, traction effects of wheels and braking effects, and says that the remedy is to reduce load or to correct improper weight-distribution. Impacts probably contribute most destructive effects. He describes in detail what happens when a truck traveling at a given speed strikes a road obstruction and how impact forces are exerted, cites tests by the Bureau of Public Roads to show that when truck equipped with solid rubber tires and traveling at 16 m.p.h. hits a road obstruction 1 in. high, impact on road surface is seven times load on tire; that is, for an 8500-lb. load on each rear wheel, intensity of blow imparted to road surface is nearly 60,000 lb. Average impact is about four times static load; with pneumatic tires it is about 25 per cent more than static load.

Impact intensity depends primarily upon mass and upon acceleration during upward and downward flight of wheel and axle; upward, when wheel hits obstruction and flies up; downward, when wheel comes down after reaching maximum upward travel, acquires velocity under force of gravity and spring pressure and hits road surface another blow before coming to rest. Regarding unsprung weight, the author states that the greater the weight of the wheels, axles and tires and the stiffer the springs, the greater the impact. Less unsprung weight and more flexible springs reduce impact. Truth of this illustrated and explained.

Engine propelled tractive effort causes driving wheels to tend to slip. The greater the speed and the smaller the ratio of load on driving wheels, the greater the tendency for wheels to spin and grind away road surface; this tendency is lessened when a truck has four driving wheels or if the load on the driving wheels is relatively large.

The first advantage gained by distributing a given load over a greater number of wheels is the reduction of load on each wheel. With the type of six-wheel construction under detailed consideration, the two rear wheels on each side are tied together by a wheel-connector that is swiveled at center where attached to spring above. When one wheel is raised, tendency is to raise the chassis only one-half distance that chassis rises in ordinary four-wheel construction. Hence, when passing over an obstruction that raises one wheel to a certain height, since center of connector tying the two axles together is raised only one-half this height, the wheels can go over larger obstructions than possible with four-wheel construction without raising chassis to more than one-half distance, provided both wheels on the same side are not raised at same time. The springs between the axles and the chassis are flexed only one-half the usual amount, even though the wheel should rise same distance as for four-wheel truck; therefore, six-wheel construction lessens impacts between wheels and road considerably.

Comparing percentages of pay load to dead weight of truck, Mr. Favary quotes for the six-wheel truck a total load of 34,000 lb., a pay load of 20,000 lb., a dead weight of 14,000 lb. and a pay-load to dead-weight ratio of 142 per cent; for a modern 5-ton four-wheel truck with a dump body and a hoist, a dead weight of 11,000 lb. and a pay load of 10,000 lb., or a similar ratio of only 91 per cent.

Supposing a demand for the transportation of 1000 tons of merchandise per day over a stated route, the author estimates the needed number of six-wheel trucks weighing 7 tons each and having a pay load of 10 tons each to be 100, or a total dead weight on the road of 700 tons; and the number of four-wheel trucks weighing 5½ tons each and having a pay load of 5 tons each to be about 200, or a total dead weight on the road of 1100 tons. In such case, an extra 400 tons per day must pass over the road with four-wheel units and, even if but 180 of these were needed to equal the performance of the six-wheel units described, it would call for 80 more trucks and 80 more drivers.

Impact tests by the Bureau of Public Roads show the impact forces of a six-wheel truck loaded with 6 tons lower than those arising from an ordinary 2-ton truck, both being equipped with pneumatic tires. Further, the ordinary 3 to 5-ton solid-tire Army truck exerts a maximum subsoil pressure of 6½ lb. per sq. in.; the 5 to 7½-ton six-wheel truck exerts a subsoil pressure of but 2 lb. per sq. in., each truck with a 10,000 lb. load.

After making an illustrated mathematical analysis of impact forces due to four-wheel 5-ton and six-wheel 10-ton trucks, Mr. Favary discusses the steering qualities of six-wheel trucks, some steered by two front wheels, others by four wheels. When the distance between the two rear axles is more than a given amount, steering through four wheels is necessary to avoid a sliding action between the tires and road surface when turning. When the two rear axles are as close together as 40 in., no sliding action takes place, as is proved by tests; consequently, in the six-wheel truck no steering linkages are required for the middle wheels, driving as well as braking is through the four rear wheels and steering by front wheels only.

In conclusion, Mr. Favary compares the capabilities of four-wheel and six-wheel trucks. Among the advantages of the six-wheel truck, he states the reduced load on each wheel results in lessened static and subsoil pressure; reduced impact forces; improved traction; reduced tendency toward wheel spinning and skidding; increased economy in freight transportation; smaller number of trucks on the road to carry a given tonnage. Further, that fewer trucks represent an important factor in decreasing road destruction, increase the traffic capacity of existing roads and minimize traffic congestion.

IN motor-truck operation, the cost of the driver's labor is one of the large items; to reduce this cost and obtain greater economy, the carrying capacity of the vehicle has been exceeded and trucks are over-

[1] M.S.A.E.—Consulting engineer, Moreland Motor Truck Co., Los Angeles.

loaded habitually. Unfortunately, an excessive load on the tires ruins the roads very quickly. To satisfy both conditions, that is, to carry heavy loads and safeguard the roads at the same time, the six-wheel truck-construction made its appearance and is a much discussed topic. By the use of six wheels under a motor vehicle, it is possible to reduce the load on each wheel and this is one factor that tends to decrease road-destruction. By employing a certain type of construction for a six-wheel truck, it will reduce the impact blows between the road and the tires far below those created by the ordinary four-wheel truck.

Causes of Road Failures

Leaving out of discussion failures due to improperly constructed roads and considering only those arising from motor-vehicle traffic, road destruction may be due to a number of causes. Classified under general headings, these are (*a*) excessive loads on the tires, (*b*) impacts between the road and the tires and (*c*) traction of the wheels and braking.

Excessive load on the tires is caused by too great a load on the truck, or by improper weight-distribution. The remedy, evidently, is to reduce the weight of the truck or that of the load, or to correct the improper weight-distribution, as the case may be.

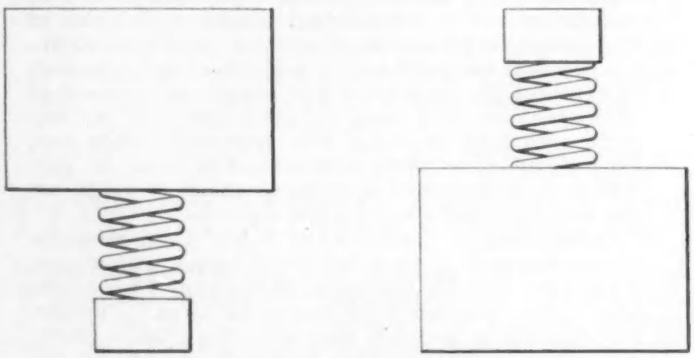

Fig. 1—Comparison Between Sprung and Unsprung Weight
In the View at the Left, the Unsprung Weight at the Bottom Is Supposed To Be Very Light; in That at the Right the Reverse Is the Case. If the Small Weight at the Left Is Hit a Quick Blow from Below, It Will Move Upward Easily by Compressing the Spring, Without Affecting the Heavy Weight Above Materially. Since Its Inertia Is Slight, It Will Not Move Up Very High Before the Spring-Pressure Will Check Its Upward Flight and, Since It Will Not Move Up So High and Its Mass Is Comparatively Small, It Is Evident That It Will Not Require So Hard a Blow To Raise the Bottom Weight Say 3 In. As If Its Mass Were Greater. In the Drawing at the Right, the Heavy Unsprung Weight Below Must Be Hit a Much Harder Blow To Move It Up 3 In., and It Will Impart a Great Amount of Motion to the Light Weight Above It As It, the Heavy Mass, Is Moving Upward

Impacts probably constitute the largest factor that affects road destruction. When a truck traveling at a certain speed hits an obstruction on a road, the impact between the road and the tire causes the wheel to fly upward and, when the energy which causes this upward motion is spent, the wheel falls on account of gravity and spring pressure from above so that, when it again makes contact with the road surface, there is a second impact. When the wheel moves upward, it impresses a force against the entire load resting on the spring; the body then begins to move upward slowly, and only after the wheel has returned to the ground does the body and its load reach the highest position. When the body descends it causes an increased pressure between the tires and the ground, and this is the third impact, though, strictly speaking, it has not the magnitude of the first two; the duration of the increased pressure on the road surface is greater than that of an impact.

In tests made by the Bureau of Public Roads it was found that, when a truck equipped with solid-rubber tires, traveling at a rate of 16 m.p.h, encountered a 1-in. obstruction on the road, the impact on the road surface amounted to as much as seven times the load on the tire; in other words, supposing that the load on the rear wheel were 8500 lb., the intensity of the impact or blow imparted to the road surface reached almost 60,000 lb. at times. From a number of tests under the same conditions, the average value was found to be about four times the static load or, in the case mentioned, about 34,000 lb. With pneumatic tires the impact was shown to be considerably less, the average being about one and one-quarter times the static load.

Intensity of impact depends primarily on the mass and on the acceleration during the upward and the downward flights of the wheel and the axle; upward, when the wheel hits the obstruction and flies up, and downward when the wheel, after reaching its maximum upward travel, comes down, acquiring velocity under the force of gravity and spring pressure and hitting the road surface another impact before coming to rest.

Effect of Unsprung Weight

As a rule the greater the unsprung weight of the wheels, axles and tires, and the stiffer the springs, the greater is the impact. A lighter unsprung weight and a more flexible spring reduces the impact. A glance at the two drawings in Fig. 1 will explain why this is so.

In the drawing at the left of Fig. 1, the unsprung weight at the bottom is supposed to be very light; in the drawing at the right the reverse is the case. Evidently, if the small weight at the left is hit a quick blow from below, it will move upward easily by compressing the spring, without affecting the heavy weight above materially. Since its inertia is slight, it will not move up very high before the spring-pressure will check its upward flight and, since it will not move up so high and its mass is comparatively small, it is evident also that it will not require so hard a blow to raise the bottom weight, say 3 in., as if its mass were greater. In the drawing at the right, the heavy unsprung weight below must be hit a much harder blow to move it up 3 in., and it will impart a great amount of motion to the light weight above it as it, the heavy mass, is moving upward. It should be noted also that the more flexible the spring is, the less suddenly will the mass above move upward, while a stiffer spring will impart a greater pressure to the upper mass when the lower mass suddenly moves up. Further, the greater the pressure exerted against the upper mass, through the spring, the higher will be the upward motion of the mass above.

Imagine now that the lower masses in the two views of Fig. 1 have been moved upward and that they are dropping down; this also holds good when they are dropping into a hole. Obviously, the heavy weight at the bottom of the view at the right will hit the road a harder blow than if the weight below were comparatively small as in the other drawing because, in this last case, a spring is interposed between the heavy mass and the road. The pressure between the tires and the road surface is the same when the truck is standing still, whether the unsprung mass be light or heavy, provided the gross weight is the same; but, when it is in motion, the impact will vary greatly with a change in the unsprung weight.

Traction of the Driving Wheels

When a truck is propelled by the power of an engine, a tendency exists for the driving wheels to slip on the

road surface due to the tractive effort. The greater the speed of travel, and the smaller the ratio of load on the driving wheels, the greater will be the tendency for slippage or spinning of the wheels. When the wheel spins, the tire will tend to grind away the road surface. When four wheels of a truck are driving wheels, or when the load of the driving wheels is proportionately large, the tendency toward wheel spinning is lessened.

With the ordinary four-wheel truck, where driving is accomplished through the two rear-wheels only, immediately after one wheel hits an obstruction it will be out of contact with the road surface for a short distance and the tire will spin as soon as it leaves the road on account of the differential gear. This tendency to wheel spinning also exists when the traction on one wheel is reduced, or when there are slippery spots on the road surface; that is, when the coefficient of friction between the tire and the road surface is reduced. With certain six-wheel constructions, even if one wheel should leave the ground, no slippage will occur unless two wheels, one on each rear axle, are out of contact with the road at the same time; this is, of course, a comparatively rare occurrence.

Road wear is also induced by locked wheels. When brakes are provided on two wheels only, the wheels will slide on the road surface to a greater extent than when brakes are applied to four wheels or when the combined load on the braking wheels is larger.

Fig. 3—Six-Wheel Truck Passing Over a Road Obstruction
Loaded with 10 Tons, the Position Assumed by the Rear Wheels When They Meet an Obstacle Is Indicated

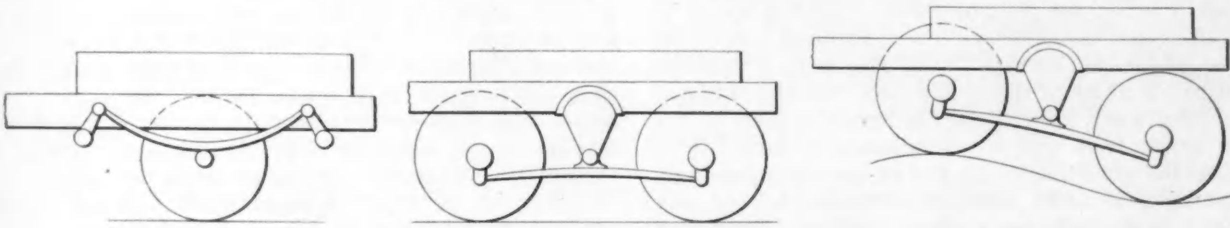

Fig. 4—Operation of the Rear Wheel-Connectors
Ordinary Four-Wheel-Truck Construction Is Indicated at the Left, and That of the Six-Wheel Truck in the Central View. When One Rear Wheel Is Raised by an Obstruction, As Shown at the Right, the Center of the Connector That Ties the Two Axles Together Is Raised Only One-Half This Height and, Since the Center of the Connector Is Attached to the Chassis, It Is Evident That the Wheels Can Surmount Larger Obstructions Without Raising the Chassis to More Than One-Half the Distance That Is Possible with a Four-Wheel Construction, Provided That Both Wheels on the Same Side Are Not Raised at the Same Time

Six-Wheel-Construction Advantages

Under the new laws of California, the maximum weight of a four-wheel truck is 22,000 lb., and that of a six-wheeler 34,000 lb. The maximum load per inch width of tire is 700 lb. By distributing a given load over a greater number of wheels, the first advantage gained is the reduction of load on each wheel. With certain six-wheel constructions, as for instance that built by the Moreland Motor Truck Co., shown in Figs. 2 and 3, the two rear wheels on each side are tied together by a wheel connector which is swivelled at the center where it is attached to the spring above. Due to this construction, when one wheel is raised, the tendency will be to raise the chassis only one-half the amount it rises with the ordinary four-wheel construction, and this is the reason six-wheel trucks of this type offer very much greater riding comfort.

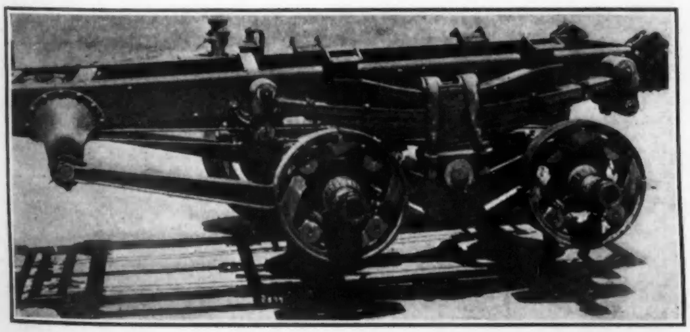

Fig. 2—Rear End of Six-Wheel-Truck Construction
The Two Rear Wheels on Each Side Are Tied Together by a Wheel Connector, Swiveled at the Center Where It Is Attached to the Spring Above. On This Account, When One Rear Wheel Is Raised, the Tendency Is To Raise the Chassis only One-Half the Amount It Rises with the Ordinary Four-Wheel Construction. Note Also the Brakeshoes, Which Are Operated by Compressed Air

An examination of Fig. 4 will make this clear. The view at the right shows one wheel raised to a certain height, but the center of the connector which ties the two axles together is raised only one-half this height and, since the center between the two axles is attached to the chassis, it is easily understandable that the wheels can go over larger obstructions without raising the chassis to more than one-half the distance than is possible with a four-wheel construction, provided, of course, that both wheels on the same side are not raised at the same time. This, however, is not a frequent occurrence.

Since the tendency is to raise the body only one-half the amount, the spring between the axles and the chassis will be flexed only one-half the amount, even when the wheel rises the same amount as with the four-wheel truck; on account of this, the impacts between the wheel and the road with such a construction are much lessened. It should be noted that one-half of all additional loads imposed on one rear wheel are transmitted automatically and taken up by the other rear wheel on the same side. For this reason, such a six-wheel construction will save the roads considerably as compared with a four-wheel construction and in no case is the impact as high, everything else being equal.

In actual test, the increased riding-comfort of such a six-wheel truck is most striking; also, the lessened impacts or pounding between the wheels and the road. In addition it is found that, while the load on each rear

wheel of the ordinary four-wheel truck having a total load of 22,000 lb. is about 8500 lb., with the six-wheel truck shown, which has a total load of 34,000 lb., the load on each rear wheel is less than 7000 lb. and the weights of wheels and axles can be reduced correspondingly. We thus have a two-fold gain, a reduced load on each wheel and a smaller unsprung weight. When a fully loaded 10-ton six-wheel Moreland truck was weighed on a scale of the Department of Weights & Measures, the weighmaster's certificate showed the total load on the four rear-wheels to be 27,450 lb., and that on the two front-wheels 7070 lb.

Economy of Operation

From the standpoint of economy in operation, the advantages are evident. In one case we have a truck that has a total weight of 34,000 lb. when carrying a pay-load of 20,000 lb. The dead weight of the truck being 14,000 lb., the percentage of pay-load to dead weight is 142 per cent. In the other instance, the modern scientifically constructed 5-ton truck with a dump body and hoist has a dead weight of about 11,000 lb. and a pay-load of 10,000 lb., or a percentage of pay-load to dead weight of only 91 per cent, and many 5-ton four-wheel trucks on the market have a dead weight much greater than 11,000 lb.

Recently, one of these six-wheel 10-ton trucks ran loaded from Los Angeles to San Francisco, averaging more than 5 miles per gal. of gasoline and a speed of 13½ m.p.h. based on average running time. A 5-ton four-wheel truck can average 15 m.p.h., with a gasoline consumption of about 5 miles per gal. Considering the matter of road wear, apart from the lesser impacts of the six-wheel truck that will be demonstrated later, it is evident that the six-wheel truck has by far the advantage.

For example, if 1000 tons of merchandise per day were to be transported over a given road, the conditions would be as shown in Table 1.

TABLE 1—TRANSPORT OF 1000 TONS OF MERCHANDISE

Details	Four-Wheel Truck	Six-Wheel Truck
Pay Load, tons	5	10
Truck Weight, tons	5½	7
Number of Trucks Required	200	100
Total Dead Weight, tons	1,100	700

According to Table 1, the four-wheel truck causes an extra 400 tons of dead weight to be moved over the road per day, requiring nearly twice as many trucks. The number of trucks is not exactly twice as many, because the 5-ton four-wheel truck averages 15 m.p.h. against 13½ m.p.h. for the 10-ton six-wheeler, or approximately 180 instead of 100 trucks, and 180 instead of 100 drivers.

Gasoline Consumption for 100 Miles

With the six-wheel truck, we have $100 \div 4 = 25$ gal. per truck, and $25 \times 100 = 2500$ gal. per day. With the four-wheel truck, we have $100 \div 5 = 20$ gal. per truck, and $20 \times 180 = 3600$ gal. per day. We thus obtain a saving of 1100 gal. of gasoline per day, or a decrease of 44 per cent in transporting this merchandise with the six-wheel truck. The oil consumption would show a corresponding saving in favor of the six-wheel truck.

Impact Tests

In tests made by the Bureau of Roads, as described by Brigadier-Gen. Albert C. Dalton,[2] it was shown that the impact forces of a six-wheel truck loaded with 6 tons were lower than the impacts resulting from an ordinary 2-ton pneumatic-tired truck. The six-wheel truck was provided with balloon tires. It was shown further that the ordinary 3 to 5-ton solid-tired Army truck exerts a maximum subsoil pressure of 6½ lb. per sq. in., and that the 5 to 7½-ton six-wheel truck already mentioned showed only 2 lb. per sq. in. subsoil pressure. Both trucks in this case were loaded with 10,000 lb.

The lower impact-forces were due very largely to the special type of spring-suspension which is only possible with a two-axle construction that permits the rear wheels to rise to a greater extent than is possible with the four-wheel truck without imparting such a great impact to the chassis. All the four rear-wheels in the Army six-wheel truck and also in the Moreland six-wheel construction are used for driving and braking.

Cost of Freight Transportation

The greater the capacity of a truck is, the less is the cost of transportation. Whatever reduces transportation cost is of benefit not only to truck operators but to the public in general. Whatever is profitable to all should be encouraged and assisted, but it is unfair that one portion of the population should profit at the expense of others.

People forget that a damaged road means not only a loss to the State, on account of the damage of the road, but an even greater loss and greater expense to truck owners. When we consider that the total operating cost of a 5-ton truck is at least $30,000 for every 100,000 miles, and that between one-quarter and one-half this amount is expended for maintenance and repairs, it is evident that a smooth road is an important factor in the "economics" of road transportation. When everyone realizes that a good road will save millions of dollars and is of benefit to all the people of the State, there will be closer cooperation between truck manufacturers, truck users, county and State officials and the public in general, and there will be a greater tendency for all of us to get together, examine the case on its merits and enact laws accordingly.

Mathematical Analysis of Impact

For comparison between the four-wheel 5-ton and the six-wheel 10-ton truck, let

a = acceleration
a_1 = deceleration
F = the force of the impact in pounds
g = acceleration due to gravity
h = the height of the drop after the wheel has been thrown upward
m = mass
P = the average total spring-pressure when the wheel is thrown upward 3 in.
p = the normal spring-pressure under full load on each wheel
s = the space in which the wheel, when dropping, is brought to a vertical stop after the rubber tire makes contact with the road
W = the total weight on each tire
w = the unsprung weight on each tire

Four-Wheel Truck.— For the ordinary four-wheel 5-ton truck, the load W on each rear tire is 8500 lb.; the unsprung weight w is 1200 lb.; the normal load p on the spring is 7300 lb.; the normal spring-deflection is 4 in.; and the spring-pressure per inch of deflection is 1825 lb. If the wheel is thrown upward 3 in., the maximum spring-pressure would be $7 \times 1825 = 12,775$ lb., and the *average* increase in spring-pressure, over that of the

[2] See *Quartermaster Review*, July and August, 1924, p. 5.

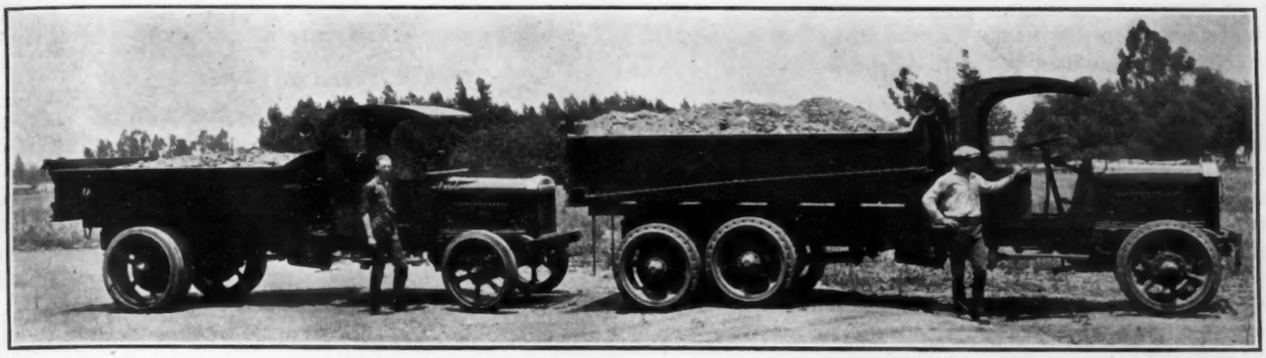

FIG. 5—FOUR AND SIX-WHEEL TRUCKS COMPARED
Each Is Loaded to Its Rated Capacity; That of the Four-Wheel Truck Is 5 Tons and That of the Six-Wheel Truck, 10 Tons

normal full-load, would be $1.5 \times 1825 = 2737.5$ lb. The average spring pressure P would be the same as that for a spring deflection of $5\frac{1}{2}$ in., or 10,000 lb.

In calculating impacts between tires and road surfaces, we assume the impact which causes a tire to be thrown upward to be equal to the impact when the tire drops down and hits the road.

To find the acceleration when the wheel, that is, the unsprung weight, is dropping under the influence of the spring-pressure and the force of gravity, we have:

$$\begin{aligned} a &= g + g\ (P/w) \\ &= 32.2 + 32.2\ (10{,}000/1200) \\ &= 32.2 + 268 \\ &= 300 \text{ ft. per sec. per sec.} \end{aligned}$$

$$\begin{aligned} h &= v^2/2a \\ &= 0.25 \text{ ft.} \\ &= v^2/(2 \times 300) \end{aligned}$$

We assume the height of the drop h to be 3 in. or 0.25 ft.; hence, the maximum velocity v is as follows:

$$\begin{aligned} v &= \sqrt{(0.25 \times 2 \times 300)} \\ &= \sqrt{150} \\ &= 12.25 \text{ ft. per sec.} \end{aligned}$$

Let us assume that the rubber of the solid-rubber tires will be depressed $\frac{1}{2}$ in., or 0.042 ft., from the time when the tire first makes contact with the road and until it comes to rest. In this case we have

$$\begin{aligned} a_1 &= v^2/2s \\ &= 150/(2 \times 0.042) \\ &= 150/0.084 \\ &= 1785 \text{ ft. per sec. per sec.} \end{aligned}$$

$$\begin{aligned} F &= ma_1 \\ &= (1200 \times 1785)/32.2 \\ &= 66{,}500 \text{ lb. impact} \end{aligned}$$

Thus we have an impact of 66,500 lb. when the wheel strikes the road from a height of 3 in.

Six-Wheel Truck.— For the six-wheel truck of certain types, these conditions do not obtain even if the load on each tire is the same, or 8500 lb. Our six-wheel-truck construction is arranged so that, when the truck is standing still, if one wheel should be raised 3 in. the body would only rise $1\frac{1}{2}$ in.

The weight distribution is as follows: The load W on each tire is 7000 lb.; the normal spring-pressure p is 6000 lb.; the unsprung weight w is 1000 lb.; the normal spring-deflection is 4 in. under full load; and the spring-pressure per inch of deflection is 1500 lb. for each rear wheel.

If the wheel is thrown upward 3 in., the average increase in spring-pressure will not be $1.50 \times 1500 = 2250$ lb., but only one-half of this or $0.75 \times 1500 = 1125$ lb.; hence the average spring-pressure when the wheel is thrown up 3 in. and until it hits the road again is $4.75 \times 1500 = 7125$ lb.

We have assumed that the body remained stationary during this period. Experiments[3] made in England and my paper on Springs and Spring-Suspensions[4] show that, when the wheel travels over an obstruction, the wheel will jump over the obstacle and come to the ground beyond it. The wheel reaches the top of its upward motion before the car body begins to move upward and, when the wheel has completed its upward jump and returned to the road, the body is then only in the first half of its upward path.

Using the same notations as before, we have for the six-wheel truck

$$\begin{aligned} a &= g + g\ (P/W) \\ &= 32.2 + 32.2\ (7125/1000) \\ &= 32.2 + 229 \\ &= 261 \text{ ft. per sec. per sec.} \end{aligned}$$

$$\begin{aligned} h &= v^2/2a \\ &= 0.25 \\ &= v^2/(2 \times 261) \end{aligned}$$

$$\begin{aligned} v &= \sqrt{(0.25 \times 2 \times 261)} \\ &= \sqrt{130.5} \\ &= 11.4 \text{ ft. per sec.} \end{aligned}$$

$$\begin{aligned} a_1 &= v^2/2s \\ &= 130.5/(2 \times 0.042) \\ &= 1550 \text{ ft. per sec. per sec.} \end{aligned}$$

$$\begin{aligned} F &= ma_1 \\ &= (1000 \times 1550)/32.2 \\ &= 48{,}100 \text{ lb. impact} \end{aligned}$$

Thus, in the two cases considered, we find the impact with the ordinary four-wheel truck to be 66,500 lb., and that with our six-wheel-truck construction, when the wheel is raised to the same height, the maximum impact is only 48,100 lb.

Fig. 2 shows a portion of the chassis with the rear wheels removed. It discloses the brakeshoes which operate on each of the driving wheels. The brakes are operated by compressed air, the air compressor being mounted at the side of the transmission or on the engine housing. Fig. 2 illustrates also the axle connector, which is swiveled in the center. Each end has a socket that is connected with the rear-axle housing, close to the wheel, and forms a ball-and-socket joint with the housing. The spring is provided with an auxiliary "full-load" spring. By making the main leaves weaker than is required to carry the full load, the suspension is more flexible with "no load" or "light" loads. Fig. 3 shows the six-wheel truck with dump body, loaded with 10 tons, one wheel

[3] See *Proceedings of the Institution of Automobile Engineers*, vol. 7, p. 459.

[4] See THE JOURNAL, January, 1920, p. 49.

being in a raised position. Fig. 5 illustrates the comparative sizes of a four-wheel 5-ton and of a six-wheel 10-ton truck, each loaded to its rated capacity.

Steering Considerations

In some six-wheel-truck constructions, only the two front-wheels are steering wheels; in others, four wheels are used for this purpose. When the distance between the rear axles causes the two pairs of rear wheels to be separated by more than a given distance, steering through four wheels is necessary to avoid a sliding action between the road surface and the tires of the rear wheels when traveling around a curve. When the two pairs of rear wheels are close together, as in the construction described, where the distance between the centers of the two rear axles is 40 in., no such sliding action takes place. To prove this, I covered the tires of the two rear-wheels on the inside of the curve with different colors of paint, one with red and one with gray. After the truck had made a semi-circle at the maximum steering angle, a large sheet of paper was placed on the pavement and the rear wheels of the truck were driven over it. The impressions so obtained disclose a very interesting fact. The middle wheel, on the forward one of the two rear axles, described the circle on the outside of the curve, while the rear wheel was on the inside. Evidently the "give" in the structure of the spring and in other parts was sufficient to permit the wheels to accommodate themselves to the correct position required when traveling around a curve. The tire impressions on the paper showed no sliding motion whatever between the rubber tire and the road surface. When the truck was running straight ahead the difference was 3/4 in. between the middle tire-tread and the rear tire-tread, indicating the fact that the tires were not pressed-on to the same extent or fitted exactly on the wheels. The difference between the marks made by the middle wheel and those of the rear wheel when making a semi-circle was 1 1/2 in.; hence, the "give" between the two rear-wheels on the inside of the curve when turning a corner with the front wheels locked to their extreme position was 3/4 in. Whether some of this "give" was due to "give" in the rubber itself, I have not determined; but it shows conclusively that no sliding action whatever exists between the road surface and the rubber, and that no steering linkages are required for the middle wheels for a construction of this kind when the axles of the rear wheels are 40 in. apart.

Other Types of Construction

In the type described, driving, as well as braking, is effected through the four rear-wheels; steering is done by the front wheels only. In another company's construction, the center axle is an addition to the ordinary four-wheel truck; steering is accomplished through four wheels, the front and the middle wheels; driving and braking are effected through the two rear-wheels only.

In our six-wheel construction, the method used to transmit a portion of the load from the middle wheel to the rear wheel, and vice versa, makes use of a horizontal member that is pivoted, not in the center, but somewhat to one side of the center, in the proportion of the loads on the middle and the rear wheels. The ends of this horizontal member are attached to the spring-shackles of the middle and of the rear springs, respectively. Inasmuch as the other ends of the springs are connected directly to the frame by spring-shackles, it is evident that only a portion of the extra load on one wheel could be transferred to the other wheel.

The load distribution in this construction is approximately as follows: On the two rear tires, 55 per cent, or 18,700 lb.; on the middle tires, 27 per cent, or 9180 lb.; on the front tires, 18 per cent, or 6120 lb. Note that the middle tires carry less than one-half the load of the rear tires and that 82 per cent of the total load is carried on the four rear driving and braking wheels. The middle axle is an ordinary front axle with the usual steering-knuckles and tie-rod.

The advantages of the six-wheel over the four-wheel truck can be summarized as follows: A reduced load on each wheel, causing lower static and subsoil pressure; reduced unsprung weight; reduced impact forces; improved traction; reduced tendency to wheel spinning; and a reduced tendency to skidding. Further, it provides increased economy in freight transportation and a smaller number of trucks are needed on the road to carry the same amount of tonnage. This last item bears an important part in the decrease of road destruction; it increases the traffic capacity of existing roads and reduces road congestion.

RAILROAD OPERATIONS

In the past the railroads have been able to handle increasing traffic without a corresponding increase in investment. In other words, they have utilized their investment more intensively as traffic has grown. Twenty-five years ago their investment was $10,000,000,000 and the number of tons of freight originating in the United States was 500,000,000. The investment per ton of freight originating was therefore about $20. Since that time the railroads have invested another $10,000,000,000. All of this investment was made at rising prices, yet in 1923 the investment account of the American railroads stood at only $15 per ton of freight originating. No other industry in the Country has made any such showing.

The important cost of operating the railroads is not the return upon investment, but operating expenses, consisting of wages, taxes and materials. Even in a year like 1923, when railroad profits were better than usual, these operating expenses absorbed more than five times as much as did the return on investment. Unless operating expenses can be held in check, the increased revenues will avail nothing.

In the past the railroads have been able to meet the rising level of wages, taxes and prices of materials by greater efficiency and economy in operation. The prices of materials in 1919 were more than twice as high as they were at the beginning of this century. Wages per man employed were 2 3/4 times as high and taxes per dollar invested were 4 times as high. Yet with all these increases the present cost of carrying a ton of freight 1 mile is only one-half larger than it was.—From an address by Dr. David Friday before New York Railroad Club.

Vol. XVI April, 1925 No. 4

Velocity of Chemical Reactions and Catalysis

By Dr. H. I. Schlesinger[1]

Chicago Section Paper

ABSTRACT

CATALYSIS is defined as the phenomenon that occurs when a substance that apparently takes no part in a chemical reaction is capable of altering the rate of the reaction; a catalytic agent, as a substance that hastens or alters the velocity of chemical reaction, but after the reaction has been completed is present in its original amount with its original properties. Inasmuch as recent researches on detonation have demonstrated the importance of a careful study of the catalytic action produced in the fuel-mixture by certain compounds, Dr. Schlesinger undertakes to clarify the subject of catalysis in general, and after showing experimentally various chemical reactions and catalytic effects, discusses from the viewpoint of a scientist the reactions that take place within the cylinder of an automobile, special reference being made to the detonation and retonation waves that are produced and to knock. Indicating how a study of fundamental facts may lead to hypotheses that may be either verified or disproved, how a speculation may be logically developed into a practical thing, he reasons that a material may be found, which, when deposited on the sides of the cylinder or on the spark-plug, would act as a permanent catalyst, or that an alloy may eventually be discovered from which cylinders may be constructed that will have a continuous catalytic effect on the fuel-mixture.

The effects of the concentration of the reacting substances, of the constant K, which is the velocity-reaction of unit concentration, and of temperature, in determining the reaction-velocity, are first explained, and the catalytic effects of platinum in increasing the reaction-velocity in the production of sulphuric and nitric acids; of palladium in hydrogen-oxygen reactions; and of water with chlorine, sodium and carbon monoxide, are cited. The Langmuir adsorption theory is described. Two explanations of catalytic effects that have been advanced are (a), that the reaction is accelerated by the molecules being adsorbed and oriented by the walls of the vessel, and the most active portions of the molecules being arranged in the positions in which they are most easily acted upon; and (b), that a catalyst, such as platinum, transforms the molecules from a non-reactive to a reactive condition by absorbing radiations of a particular wave-length and returning to the reaction-mixture those of another wave-length that it is capable of absorbing.

Other substances have the property of preventing catalytic action, apparently by poisoning the catalyst, and it is only when these poisons are removed that the reactions become feasible. Among such substances are organic amines, the iodine compounds, the arsenic compounds, the sulphur group, including selenium and tellurium, and lead, which is the worst of all. The poisons are supposed to act either by transforming the catalytic agent into a non-reactive compound or by coating it so that the substance to be catalyzed cannot come into contact with it.

The conditions in an automobile cylinder are very complex and very different from those found in a laboratory. The only chemical reaction analogous to them is that of flame. Associated with the flame as it passes forward through the cylinder are brilliant light and high pressure. Two waves are produced: a forward or detonation wave and a backward or retonation wave. The detonation wave is the cumulative sequence of increasing temperature, velocity and expansion; the retonation wave, a reaction to the high pressure developed by the detonation wave and sent back in the opposite direction.

The three theories of knock are that it is caused (a) by the mechanical impact of metallic parts, (b) by spontaneous ignition and a simultaneous development of pressure throughout the cylinder and (c) by the setting-up of a large detonation wave having large differences of pressure and of wave-front which give rise to vibratory deformations that produce sound.

One theory of the function of knock-preventive material is that it lays down in the cylinder a catalytic agent that will lower the ignition temperatures of other fuels so that they will begin to burn before the flame gets entirely through, and will show the same phenomena throughout. Another theory is that there is introduced in the dope a negative catalyst that slows down the reaction and prevents it from attaining to a detonating velocity. When viewed as a catalyst poison, the function of an anti-knock material is to counteract the catalytic effect of the walls of the cylinder, spark-plug and other substances present within the cylinder, and to enable the reaction to take place at its normal velocity, which is slower than the catalyzed velocity and not sufficiently fast to produce a detonation wave.

The fact that certain substances are effective both as catalyst poisons and as knock-preventives and in the same degree indicates that there is a certain parallelism between catalyst poisons and knock-preventives that is worthy of further investigation.

WITHIN the last few years a considerable amount of experimental work has been done by automotive engineers with the purpose of controlling the chemical reactions that take place in the cylinders of an automobile engine in such a way as to increase the efficiency of the engine. An understanding of the fundamental principles of physical chemistry, upon which such experiments must be based, is necessary in order that one can appreciate the work that is being done and have some basis of judging to what results it may finally lead. It was therefore suggested to me that I attempt to recapitulate some of the most important principles relating to these recent developments in automotive research. Necessarily, because of the limitation of time, this recapitulation can touch upon the various phases of the subject only in the briefest way, but any hesitation that I felt on this account was overruled by your program committee, who assured me that a discussion of this sort would be of interest to you.

It is a well-known fact that different chemical reactions proceed with vastly different speeds; the rusting of a piece of iron may require months before it is complete, while the explosion of a stick of dynamite occupies

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but a fraction of a second. Nevertheless the fundamental principles that underlie the phenomenon of chemical reaction are the same in each case. Some chemical reactions are complex, involving a large number of molecular species; others are simple. Unfortunately the reactions taking place in the cylinder of an automobile engine belong to the former group. In spite of this fact, we shall arrive at a clear picture of what is going on within the cylinder if we begin our discussion with the simplest possible case.

Imagine that we have a reaction between any two gaseous substances. Let the reaction be one in which no change of volume results and during the course of which the temperature can be kept constant and uniform. Now we all know that reaction takes place between the molecules of the reacting substances and that it is necessary, therefore, for these molecules to come into contact with one another. Molecules are in continuous motion and consequently there will be impact between them. At the times when these impacts occur, reaction will occur. That does not mean that a reaction will occur at every impact; it means simply that the number of reactions between molecules will be some function of the number of impacts, presumably a direct proportionality.

It is clear, that since the molecules are moving about, the more molecules there are in a given space the more often will they come into contact with one another and, therefore, the greater will be the chance of reaction. In other words, the reaction velocity will be proportional to the concentration of the reacting substances and, if the reacting substances are gases, we can say that the reaction velocity will be proportional to the partial pressure of the gases. Applying this idea to the reaction between two substances, a and b, we can then write

$$v = k \cdot C_a \cdot C_b \cdot p_b$$

or

$$v = K \cdot p_a \cdot p_b \qquad (1)$$

In these equations, v represents the reaction velocity, the k and K are constants, p_a and p_b are the partial pressures of a and of b, and C_a and C_b are the concentrations of a and of b, expressed in units that are proportional to the number of molecules. Of course, to engineers it is self-evident that an equation in this form is not very useful, because the concentrations are continually changing when the substances a and b react with one another, since the amounts of substances a and b continuously become less. Therefore, instead of using this form of equation, we use a differential equation; but at present we are not discussing equations but underlying facts, and it will not be necessary for me to develop the simple differential equations used in working with reaction velocities.

Factors Determining Reaction Velocity

With these equations in mind, we can discuss a little more fully the factors that determine the reaction velocity in a given mixture. In the first place, it is self-evident that it will be dependent on the concentration of the reacting substances a and b. This fact is made use of very often in chemical industry. If we want to make a reaction go fast we ordinarily have the concentrations of the reacting substances as high as possible. That can be shown by a very simple experiment.

A mixture of iodic acid, HIO_3, and sulphurous acid, H_2SO_3, reacts, with the liberation of iodine. In order that the iodine, which is not intensely colored in dilute solutions, may be seen, I shall introduce into each solution a little starch. The starch acts on the iodine and gives a blue color that makes it more easily visible at a distance. I shall put the same amount of starch into each solution. One solution contains the iodic acid, the other the sulphurous acid. Into one of the flasks I shall introduce 10 cc. of sulphurous acid, into the other, 5 cc. We introduce the sulphurous acid into the two flasks as nearly simultaneously as we can, then shake them and watch the result. We see that in the more concentrated solution 10 or 15 sec. elapse before the blue color appears and that the other goes much more slowly; in other words, as you see roughly from this experiment, the reaction velocity is proportional to the concentration of the reaction mixtures. Therefore if we wish to make a reaction go rapidly, we must increase the concentration of the reacting substances. Certain complications may enter, but it is not necessary to take them up.

The second factor that enters into the velocity of chemical reaction is the constant k, we are assuming now, of course, that the reaction is going on at a constant temperature. If we imagine that the concentration of each of the reacting substances is equal to one, that is, 1 gram molecule in the usual terminology, we shall see that this constant k is nothing else than the velocity of reaction at unit concentration. It is a very striking fact that the velocity of different reactions at unit concentration at the same temperature varies enormously from reaction to reaction. This term k is as specific a property of a given mixture as any property can be. It can be used, for example, to identify chemical substances in unknown mixtures.

Why are the reaction velocities so enormously different for different reactions? In some cases we can offer an explanation. We all are familiar, of course, with the fact that when we put sodium into water it reacts with the water with enormous velocity, whereas if we put iron into the water it reacts very slowly. In other words, there is a difference in the specific constant of the two substances.

We believe that we know what the difference is between these two cases. You will remember perhaps the lecture[2] given before the Society last year at the University of Chicago, in which the atom was shown to be a sort of solar system with a positively charged nucleus surrounded by satellites of negatively charged electrons. The reason that sodium reacts with water to liberate hydrogen is that sodium has a very great tendency to give up its electrons to the hydrogen ion present in the solution. Iron has a much smaller tendency to give up its electrons and to become positively charged. That tendency can be measured; and the difference in the reactivity of the iron and of the sodium is caused by the difference in the tendency that these two elements have to lose their electrons.

We know also that, as a general thing, ionic reactions are very rapid. When a solution of sodium hydroxide is mixed with one of hydrochloric acid, the reaction occurs practically instantaneously. It has often been said that the reason for this is that free ions are present in the solution in a condition in which they can readily react. This explanation alone is not entirely satisfactory. For example, prussic acid, HCN, is ionized to an extent of about 0.001 per cent of the total amount present in a one-tenth normal solution. Yet it will react with sodium hydroxide as fast as does hydrochloric acid which is nearly 100 per cent ionized. The number

[2] See The Journal, December, 1923, p. 466.

of ions present in a prussic acid solution is so small that it seems improbable that the great speed of the reaction can be due solely to their presence. In the case of some complex metal cyanides, which react instantly with hydrogen sulphide, it has been shown by calculation that it would be necessary for the ions present to be moving with a velocity greater than that of light to account for the speed of the reactions, if the reaction is to be ascribed entirely to the ions. Even if we do not agree with Einstein that the velocity of light is the greatest possible velocity, I think none of us would accept a theory of reaction velocity that requires the ions to be moving with such speed. Therefore, we may say that, even in this very simple case of reaction, the reason for the extraordinary velocity is not understood. Why different substances have a different specific reaction rate is still one of the problems of chemistry, which, although of the greatest importance, has been attacked least successfully.

For our particular purpose, it is sufficient to bear in mind that different substances do react with different specific reaction velocities; and it does not make much difference what the fundamental reasons underlying the differences are.

Before leaving equation (1) I wish to discuss another factor, namely, the effect of temperature. Increased temperature means increased velocity of the molecules. Since temperature is a measure of the mean kinetic energy of the molecules, $\frac{1}{2}mv^2$, we can see that if we raise the absolute temperature, we raise the square of the velocity. This, then, might appear to be the explanation of the fact that, as we raise the temperature of a reaction mixture, we invariably increase the speed of the reaction. But when we investigate this a little more closely we find that the explanation will not hold.

Suppose we have a reaction going on at 0 deg. cent. (32 deg. fahr.) and raise the temperature 10 deg. cent., that is, we raise the temperature from 273 to 283 deg. absolute or approximately 4 per cent. This is a measure, then, of the increase of the square of the velocity of the molecules. Since we are considering the case in which two molecules are reacting and since each will have its velocity increased, we can expect a 10-deg. rise of temperature to produce an increase of reaction velocity from, let us say, 2 to 4 per cent. As a matter of fact, we shall get an increase of reaction velocity from 100 to 300 per cent for every 10-deg. rise of temperature. In other words, the simple explanation of the increase of reaction velocity is not worth much, since it can account for only a very small fraction of the actual increase.

This is another problem in chemistry that has not been scientifically solved at the present time. I might call your attention to one possibility. When we raise the temperature of a substance, all the heat we put in does not go toward increasing the velocity of translation of the molecules. We have an increase in the velocity of translation and also an increase in the internal energy of the molecules, as is shown by the fact that the specific heat of a polyatomic gas is not what we should calculate it to be if all the heat went into translational velocity. If we imagine that a part of the heat we put into the gas goes toward increasing the internal energy of the molecule and if we assume, furthermore, that some of the molecules get a much larger increase of internal energy than others, we can, perhaps, get an explanation of this enormous increase in reaction velocity. I shall come back to this phenomenon in my discussion later on.

The following equation is frequently given to express the experimental facts with regard to the increase of reaction velocity with temperature:

$$dluk/dt = E/RT^2$$

or

$$k = Se - E/RT \qquad (2)$$

These, then, are the important factors in reaction velocity: (*a*) the specific constant of reaction velocity, that is, the reaction velocity for unit concentration; (*b*) the concentration of the reacting substances, and (*c*) the temperature.

If we return for a moment to our experiment and examine the phenomena more closely we shall notice something rather peculiar. It took approximately from 10 to 20 sec. for the color to appear, but then it appeared suddenly. If the reaction was slow enough to require 10 or 20 sec. for the color to appear at all, we should anticipate the phenomenon to be a gradual one. To show that the sudden appearance of color is not due to anything used in the color test, I shall add some iodine to a solution of starch of about the same concentration as used in the experiment. I have 10 cc. of starch solution, and shall add it to approximately the same volume of water, then put into the solution a very dilute solution of iodine, the same substance as that which turned the solution blue. If I put in a little of the iodine solution, the color produced is very slight; as a matter of fact I do not think it can be seen at all from a distance. As I add it gradually, a faint bluish tinge is noticeable; if I add a little more the color gradually deepens. Before I get a color that is equivalent to that of the preceding experiment, I shall have to add a large quantity of this very dilute iodine solution. The color goes gradually through all the stages, from colorless, through light blue, a very distinct light blue, and ultimately to the deep blue we got in the first experiment. The change of color was not gradual in the first case even though the reaction required an appreciable time interval.

How can we account for the fact that the color appeared with such great suddenness? Evidently something must have happened to the orderly progress of the reaction so that when a certain stage was reached it went with an increased speed that made the color appear suddenly. It is a phenomenon like that of detonation in an explosive mixture, but the analogy is a poor one. The thing that happened in this particular reaction mixture, which made it go so suddenly, is that one of the products that was formed in the reaction is a catalytic agent; as it is formed it makes the reaction go faster without apparently taking part in it, and as it accumulates its influence on the reaction velocity increases. The sudden appearance of color has been ascribed to the occurrence of a series of reactions. Therefore, from a practical point of view, just as fundamental as are the influence of concentration, temperature and reaction constant is the question of catalysis.

Catalysis Defined

Let us, therefore, define the term catalysis. It may be defined as the phenomenon that occurs when a substance, which apparently does not take any part in the reaction, is capable of altering the rate of the chemical reaction. Another way of defining the term is to say that the catalytic agent is a substance that hastens or alters the velocity of chemical reaction, but, after the reaction has been completed, is present in its original amount with its original properties. In the second definition I do not enter into the problem of whether the catalytic agent takes part in the reaction, I simply say that

it is there at the end of the reaction as it was at the beginning.

Now, let us give one or two illustrations of catalysis. A very interesting example is found in the manufacture of sulphuric acid. As you know, when we burn sulphur in the air we get sulphur dioxide. If you ever have burned sulphur in a closet to kill moths and have gone into the closet a week afterward, you know that sulphur dioxide does not disappear very quickly. Nevertheless, the sulphur dioxide that we get by burning sulphur in air is capable of reacting with the oxygen of the air to give sulphur trioxide. Sulphur trioxide dissolved in water gives sulphuric acid. The reaction of sulphur dioxide with oxygen under ordinary conditions is so slow that we can burn the sulphur in the closet and a week or more later still notice its presence. It is manifest that if we were to make sulphuric acid in this way we should not get much made.

It has been found, however, that when a mixture of sulphur dioxide and oxygen is passed over finely divided platinum containing heat, let us say on a base like asbestos, the reaction will proceed with a very appreciable velocity; a large proportion of the sulphuric acid made today is made by this method. In other words, the platinum, which is used over and over again, if the conditions are right, makes the reaction go faster although, so far as chemists can tell, even by very careful examination, it apparently takes no part in the reaction.

Another interesting illustration, interesting perhaps chiefly because it played such an enormous role in the war, is in the manufacture of nitric acid. Germany could not have gone to war if it had had no means of making nitric acid. Chilean saltpeter was out of the question because in the event of war that source of supply would be cut off. Germany was particularly careful not to begin the war until it had found a method of making nitric acid from the nitrogen contained in the air. The method used was to make ammonia first by combining nitrogen with hydrogen. Nitrogen and hydrogen can be put into a vessel and kept together in the vessel for a number of years without reacting; but in the presence of a catalytic agent, the nature of which has never been completely divulged, at high temperature and high pressure the nitrogen and hydrogen will combine to form ammonia.

We are all familiar with ammonia. We know it does not burn readily in air. If we wish to make ammonia burn in air or in oxygen, we must heat it to a high temperature; and under these conditions nitric acid is not formed. But if we take ammonia, mix it with air and pass it over platinum, the ammonia and oxygen unite to form nitric acid. I can show you that by a very simple experiment. If a little concentrated solution of ammonia be placed in a flask and a slightly warm coil of platinum wire be introduced into the latter, a reaction will commence, the ammonia will burn in the air with sufficient velocity so that the heat of the reaction will keep the platinum wire at glowing temperature. If I remove the platinum wire for a moment from the vessel and introduce it again, the wire will spontaneously heat up.

This is only one very simple illustration of the phenomenon of catalysis. The manufacture of such substances as the fat substitutes made from cottonseed oil is another. Hydrogen is used as a reducing agent but it does not react with sufficient rapidity unless a catalytic agent is present. I could cite many other illustrations chosen from chemical industry or familiar phenomena of our daily life. But I prefer to take up briefly the question of the nature of the phenomenon, although this, too, is not by any means thoroughly understood.

Catalysis is so varied a phenomenon that it would be futile to anticipate that one explanation should serve for all possible catalytic agents. I wish, therefore, to take up a few of the explanations that have been given. One is the explanation that we should look for first on the basis of the fundamental equation for reaction velocity, namely, the possibility that the introduction of a catalytic agent merely increases the concentration of the reacting substances. For example, palladium in certain forms is capable of dissolving or absorbing in some way 900 times its own volume of hydrogen. Therefore, we can understand readily why it is that when hydrogen is brought into contact with palladium it might react at the surface of the palladium with a greater velocity with, for example, oxygen than it would if there were no palladium present.

One of the most effective and most common of catalytic agents is water. Chlorine and sodium ordinarily react with great violence, but we can drop a piece of sodium, even though its surface is perfectly clean, into perfectly dry liquid chlorine without the occurrence of the slightest reaction. Another illustration of this type of catalysis is found in the familiar reaction between gaseous ammonia and hydrogen chloride. If both substances are absolutely dry no reaction takes place, but the introduction of a trace of water causes the formation of ammonium chloride with great rapidity.

An interpretation, possible in many instances, of the catalytic action of water is that it ionizes the substances that are to react; but that is an explanation that can hold only in certain cases. For example, it cannot be applied to a case that is of interest to automotive engineers, namely, that of carbon monoxide, which does not burn in perfectly dry oxygen. In this case the catalytic action is explained by Dixon, as the result of his work on explosion waves, on the assumption that carbon monoxide reacts first with water as follows:

$$2CO + 2H_2O = 2CO_2 + 2H_2$$

The two hydrogen molecules then react with oxygen to give two molecules of water; in other words the total amount of water before and after reaction is the same. Another explanation assumes that hydrogen peroxide is an intermediate product. Therefore, unless we had some means, such as the explosion wave, to determine the exact course of the reaction, we should think the water took no part in it and should ascribe the effect of the water to some unknown catalytic influence.

Such indirect routes of arriving at a final result through a catalytic agent are undoubtedly very common phenomena and, in many instances, are undoubtedly the explanation of catalysis. In most catalytic reactions, however, and particularly in those which are of special interest in the present discussion, this type of catalysis is probably not of great importance.

The types of catalysis that probably are most closely related to the phenomena occurring in the cylinder of a gasoline engine are those which are frequently exerted by the walls of the vessel in which a reacting gas mixture is contained and those which are due to some type of radiant energy. In such cases neither the formation of intermediate compounds nor the absorption of large quantities of the gaseous reactants can be assumed to be the chief cause of the catalytic action, for even vessels of glass, which neither absorb nor react with most gases, are capable of acting as catalysts. Unfortunately my time is too limited to allow me to give you

more than a brief outline of the theories that are being formulated at the present time to account for this class of phenomenon.

The first of these theories may be called the adsorption theory, which has been developed most fully by Langmuir. When any solid surface is placed in contact with a gas, a very thin layer of gas is condensed on the surface. Solid substances, for example, that are exposed to an atmosphere containing water vapor must be looked upon as being coated with a very thin layer of water. The latter is very firmly held by the surface; it cannot be removed by ordinary processes, such as wiping the material or gently heating it. The same thing is true of gases other than water vapor. It is, for example, a well-known fact that if one wishes completely to remove gas from a glass vessel it is necessary repeatedly to heat the vessel to as high a temperature as possible and at the same time to keep it connected with an efficient vacuum pump. The forces that cause the gas to adhere to the walls of the vessel are, according to Langmuir, not analogous to gravitation, for they vary with the nature of the gas and of the material of which the vessel is made. They are, in other words, chemical forces.

But Langmuir goes even farther in his analysis of the forces that are responsible for this phenomenon of the adsorption of gases. I can explain his point of view most clearly by an illustration. Organic acids may be looked upon as consisting of two parts. For example, acetic acid, CH_3COOH, can be thought of as being constituted of a hydrocarbon residue, the CH_3 group, and COOH, the acid group. Specific surfaces are then considered as having different attractive forces upon the two different groups; for example, water would attract the COOH group more strongly than it does the CH_3 group. We make this assumption because water is incapable of dissolving hydrocarbons. The more hydrocarbon groups there are in a compound like acetic acid, or the heavier the "hydrocarbon residue" in the molecule is, the less soluble does the acid become. Thus the acid $C_{17}H_{35}COOH$ is insoluble in water. The result of this differential attraction of the water for the acid molecule will be that in a water surface containing an acid like acetic acid, or in a water surface covered with a film of the heavier organic acid, the molecules of the acid will not lie in disorderly fashion. They will be oriented in such a way that the part that is more strongly attracted by the water will be turned toward the water and the other part will be turned away from the water surface, much like ducks on a pond with their heads in the water and their tails sticking up. In the case cited the acid group are the duck's heads and the "hydrocarbon residue" their tails. Of course, what has been said about water and organic acids might be applied to any surface in its relation to the attractive effect on any kind of molecule that consists of two or more parts having rather different chemical properties.

This picture of the orientation of adsorbed molecules offers a possible explanation of the catalytic effects which the walls of a vessel may exert on a reaction going on within the vessel. Suppose the vessel contains a substance AB which is to react with some other substance C. If the parts A and B of AB are chemically different it is likely that C will react with either A or B of the molecule but not with both indifferently. It is therefore not a sufficient condition for reaction that AB and C should strike each other; it will be necessary for C to strike the right part of AB, let us say B. Suppose further that the wall of the vessel adsorbs AB in such a way that the portion B of the molecule is turned away from the wall. We can see readily that this orientation will increase the probability of effective impact between AB and C. As a result both of adsorption on the walls, which has there increased the concentration of AB and, because of the favorable orientation of the latter, the velocity of the reaction must become greatly increased and the wall is acting as a catalyst. This, of course, is a very hurried picture of this fascinating hypothesis, not exact in all its details, but it is all that we have time for.

The other important modern theory of catalysis must receive even briefer treatment. Before I can take this theory up, I must refer to an interesting matter though a rather specialized one. Those of you who recall your physical chemistry may have wondered why I chose as the simplest type of reaction one in which two molecules react with each other, rather than one in which a single molecule is undergoing a change into something else. I had two reasons for doing this. To make my first reason clear, let us investigate the cases of the latter type of reaction. Early in the study of reaction velocity a reaction of this type was thought to have been discovered, namely, the decomposition of arsine into arsenic and hydrogen. The chemical equation for the reaction could be written

$$AsH_3 = As + H$$

but such an equation would be severely criticized by chemists because ordinary hydrogen does not consist of hydrogen atoms nor does arsenic vapor consist of arsenic atoms. To fit the known facts we should have to write

$$4AsH_3 = As_4 + 6H_2$$

The latter reaction, however, is no longer one which could be considered monomolecular; it is quadrimolecular and the velocity should be proportional to the fourth power of the arsine concentration. As a matter of fact, it was found that the velocity actually is proportional to the first power as would be expected if the first equation were correct. Chemists being on the whole a rather ingenious set of individuals found what seemed at first glance a good explanation, namely, that the first equation is correct, but that the arsenic atoms combined with each other to form arsenic molecules and the hydrogen atoms united to form hydrogen molecules so rapidly that the velocities of these secondary reactions could not be measured and that the only measurable reaction was the first one. This explanation seemed very satisfactory until it was found that, while the reaction velocity was always proportional to the first power of the arsine concentration, its actual value depended upon the shape of the vessel. Another interesting fact about this reaction was the discovery that its temperature coefficient was about 2 to 4 per cent per 10 deg. as required if the effect of temperature is solely that of speeding-up the molecules, whereas all other types of reaction have a coefficient of from 200 to 300 per cent for the same temperature interval. Practically all monomolecular reactions thus far studied exhibit the same peculiarities as do the one discussed; in fact, all but two. The reason for these peculiarities was soon discovered. The reactions that exhibit them are not really monomolecular at all; they are reactions in which the velocity is exceedingly slow in the interior of the vessel but is enormously catalyzed by the walls of the containing vessel. What is really being measured is not the rate of reaction but the rate of diffusion to the walls. This rate, of course, is proportional to the first power of the concentration; it would depend on the shape of the vessel, since vessels

of different shapes have different cross-sections for the same volume; it would have a temperature coefficient calculable from the kinetic theory of gases because it is merely a diffusional velocity. I therefore did not consider monomolecular reactions as the simplest cases because so few truly belonging to this class are really known.

But there was also another reason. If more than one molecule is engaged in a reaction, it is easy to see why the reaction takes time for its completion since at least two molecules must meet in order to react and these meetings occur only at definite intervals. But if a single molecule is decomposing, what is the incentive that makes it decompose? If one of them decomposes, why do not they all do so? It might be suggested that the molecules must hit each other in order to bring them to the point of reaction. But if a blow is all that is required the introduction of an inert gas ought to affect the rate of reaction, and this is not true. I may say that this question is another one of those which have not yet received a satisfactory solution, but a number of very suggestive hypotheses have been proposed and one in particular should be of interest to you.

According to this hypothesis not all the molecules of a mixture are in the same condition; some are reactive while others are inert. What then changes the inert molecules into the active ones? A molecule even of a relatively simple substance is a very complex affair, consisting of atoms which in turn consist of electrons and nuclei. All these parts must be looked upon as vibrating and vibrating in some particular mode or with some particular frequency. Consequently the molecule is a complex system of resonators which will respond to radiant energy of some frequency or frequencies. If the right sort of frequencies is supplied, the natural vibrations of the molecule will increase, it will absorb radiant energy and become activated. A catalytic agent according to this theory transforms energy received from without the reacting system to the particular frequency required by the particular reaction which is catalyzed by it. The amount of energy required to transform the inactive molecules into their active state is then the term E in equation (2) that was mentioned earlier in the paper. You can see that such a theory as this may be used also to explain the effect of spark discharges in catalyzing chemical reactions, such as occur in the electrical methods of making nitric acid from the air and possibly at the spark-plug of an engine. The theory has not yet met with the success that would be necessary fully to establish it even as a provisional working hypothesis for it has failed to give numerical agreement between deductions made from it and the actual observations; but that may be due to thus fact that in such calculations the molecules have thus far been considered as simple resonators whereas they unquestionably are complex. Unfortunately I cannot take the matter up more fully tonight.

Negative Catalysis

Before I leave the subject of catalysis, I should like to take up one other phase of it, namely, the question of negative catalysis. There are some substances which by their presence retard chemical reaction. It has been assumed that the process of retardation is of a similar character to that of acceleration. Closely related to the phenomenon of negative catalysis is that of the "poisoning" of catalyzers, or the influence that some substances have of inhibiting the action of catalytic agents. The reaction that I mentioned as our first illustration of catalysis, namely, the reaction between sulphur dioxide and oxygen as catalyzed by the presence of platinum-black, was known, I believe, some 75 years ago. Although it is one of the easiest ways of making sulphur trioxide, and, therefore, of making sulphuric acid, it was of absolutely no practical value up to, say, 25 years ago. The reason that it was of no practical value, although it worked well on a small scale, was that in the laboratory we are working with pure sulphur dioxide and pure oxygen, and in the plants we are working with impure materials. The sulphur dioxide carried with it certain substances such as arsenic compounds which gradually stopped the catalytic action of the platinum. You can see readily that if a catalytic agent, such as platinum, has to be thrown away or regenerated every few hours, the process employing it is worthless. Only after it had been discovered that certain impurities in the gases prevent catalytic action did the process become successful. Means of removing these poisons from catalysts were discovered, and when these means were employed the reaction became feasible and was applied. That is true of practically all catalysts. It is quite possible that negative catalyzers are really catalyst poisons, the presence of which prevents the action of unknown positive catalysts whose aid is essential to the reaction.

I want to give you the names of the substances that are catalyst poisons because I shall refer to them later. In the reactions in which platinum acts as a catalyst we find that organic amines are catalyst poisons, but not very serious poisons. After getting a dose of this poison a catalyst recovers quickly; and it takes a large dose to kill a catalyst. Far more poisonous in general, are the iodine compounds. Still more poisonous are compounds of arsenic. They are among the worst poisons. I do not know in what order to put the next substances. Perhaps more poisonous, in some cases, are the components of the sulphur group. In that group are selenium and tellurium. But perhaps the worst thing you can do to a catalyst is to put a little lead into it. That is fatal to it in no time at all. These substances are so poisonous that one molecule of a catalyst poison in 25,000,000 molecules of the solution to be catalyzed may destroy the effectiveness of the catalyst.

How do catalyst poisons act? They react with a catalytic agent and transform it into a non-reactive compound; or they coat the catalytic agent so that the substance to be catalyzed no longer comes into contact with it. As I have pointed out, one of the important and interesting theories of catalysis is that the surface of a solid adsorbs the gaseous materials that are to react in the space surrounded by that surface. Now, suppose the catalyst to have greater ability to adsorb some of these poisons than it has to adsorb the substances that are to react. Under these conditions the surface of the catalyst can be completely coated by adsorption with molecules that are not taking part in the reaction and thus the molecules that are to be catalyzed cannot get at the surface of the catalyst. The same thing would be true if we had a compound formed on the surface so that the surface is coated. In many cases, however, this mechanism, although it has been suggested, is not a likely one. For example, it seems to me perfectly absurd to imagine a sulphide of platinum being formed under conditions under which sulphur compounds act as catalyst poisons for platinum. Whatever the theory is in any given case, substances probably act as poisons because they alter the surface of the catalyst.

I should like to point out again that what I have thus far been discussing is a condition entirely different from that which you might have in an automobile. I have been discussing a reaction that takes place quietly and gently throughout the reaction mixture at a constant temperature and without change of pressure, so that everything is relatively simple from a theoretical point of view. In an automobile cylinder everything is entirely the opposite. The reaction does not take place uniformly throughout the vessel; it begins at one end of the vessel and travels through the gas. At the same time the piston is moving up and down inside the cylinder and producing all sorts of disturbances. The gas at the beginning of the reaction is not at rest, as I have assumed here, but is moving about in ways that probably no one knows, a result of having been blown into the cylinder at considerable velocity. The only analogy we have in chemical reaction is that of flame. Some important experiments by Dixon are, I think, the foundation work in the matter of flame in chemistry, and though, of course, much has been done since their time, I shall describe them briefly.

When we have in a tube any mixture of gases that can react with one another, as, for example, carbon disulphide and nitric oxide, and we start the reaction at the end of the tube, the reaction may travel through the tube in the form of a flame. We can distinguish three things that may occur under those conditions. In the first place, the reaction may proceed through the tube slowly, with a slightly accelerated velocity, and continue through the whole tube in that way; that sort of reaction we need not discuss. The second type is a reaction that travels through with a fairly constant, or slightly accelerated, speed until it reaches a certain point in the tube where the flame begins to waver back and forth and then goes out; that again is a type of flame in which you are not interested particularly. In the third kind of reaction the flame likewise starts with a slowly accelerating velocity, reaches a definite point within the tube, flickers back and forth for a very short period and suddenly travels through the remainder of the tube with enormous velocity. That is the type that has been discussed very much lately in the automobile world. It is the type of reaction the fundamental wǒrk of which was done by Dixon in the last part of the last century.

Dixon's Studies of Reaction Velocity

Dixon studied these reactions in a tube some distance from a film moving downward. Optical devices were used to focus a picture of the tube on the film; as the film traveled downward the flame traveled horizontally through the gas. You can see readily that if the film were moving rapidly and the flame slowly there would be an almost vertical streak of light on the film; if the velocity of the flame were nearly the same as that of the film, the streak of light would be at an angle of about 45 deg.; if the velocity of the flame were very great compared with that of the film, the streak of light would be horizontal. By measuring the angle between the streak of light and a horizontal or vertical line the velocity of the flame can be measured.

Dixon found that, in general, these flames start relatively slowly. They travel a certain distance spreading out in the tube and, after a moment of hesitation, start forward with enormous velocity and pass through the tube. Associated with the initiation of the rapidly moving flame are a brilliant light and a high pressure. At the moment of change to the extremely rapid flame, another wave is sent back in the opposite direction through the gas, which already has partly burned. The first wave Dixon called the detonation wave, and the wave that is thrown back as a result of the sudden development of pressure at this point he called the retonation wave. The detonation wave moves with a velocity slightly greater, in general, than does the retonation wave.

What are the characteristics of these waves? The detonation wave moves through the reaction mixture with a velocity approximately twice that which we should calculate for the velocity of sound, for a reaction mixture of the particular temperature that is assumed to exist in this reaction mixture at the time the flame is passing through it, and of the density of that reaction mixture. Of course, you can understand that the calculation of what the velocity of sound ought to be in such a mixture is a difficult thing to make. You must calculate the temperature on the assumption that all the heat of the reaction is maintained in the mixture, that is, on the assumption that the reaction is so rapid that no heat has time to escape. The calculation is complicated by the fact that the specific heat of the gas changes with change of temperature. Another difficulty is that the high temperatures may cause secondary effects, such as dissociation of some of the gaseous products. For these reasons Dixon actually measured the velocity of a sound wave in the exploding mixture by means of the following described device:

A detonation wave is sent through such a tube and by some sort of metallic membrane, a sound wave is started so as to follow behind the detonation wave. It is thus found that the sound wave actually does travel through the mixture at the same rate as the detonation wave. This velocity is, as I have said, twice as great as the calculated velocity of sound. The explanation is that the velocity of sound is doubled because the molecules of gas through which the vibratory wave is passing are also moving forward. There are certain reasons for doubting the correctness of the explanation; there is no question as to the facts, as we know from the experiment just described.

Now, what causes this extremely rapid detonation wave? Why should it suddenly start? When I discovered that I really did not know of a good explanation I made a search of the literature on the subject but could not find an explicit one. Probably it is so simple that no one has thought it necessary to write an explanation. Picture to yourselves this situation. A reaction is starting in a reaction mixture; the reaction may be giving out a little more heat than is being lost by radiation; as a result the temperature rises; this increases the reaction velocity; from this it follows that the amount of heat liberated in unit time becomes greater; consequently, the rate at which the temperature rises and the reaction velocity increases becomes more rapid. The sequence is one of cumulative effects. Furthermore, the increase in temperature produces an expansion of the gases toward the open farther end of the tube. Ultimately, however, the expansion of the gases becomes so rapid that the inertia of the gases in the farther end of the tube prevents further expansion. When this moment arrives, there is added to the effect of the ever increasingly rising temperature the effect of increase of pressure. Now the velocity of the reaction has become so great that the gases at the farther end of the tube cannot move with a speed even approximating the rate of expansion of the reacting gases and a relatively sudden compression must result. This compression starts forward a compression wave that is

analogous to a sound wave. At the same time, the gases in the farther part of the tube have been so highly compressed that, from them, there returns what might almost be looked upon as a reflected wave, which Dixon calls the "retonation wave" and which he explains as a sort of reaction to the force in the forward direction.

At the time when this sudden increase of pressure occurs, we have also a sudden increase of temperature and, as I have pointed out, this sudden increase of temperature means much greater activity and, consequently, the temperature reached at the moment that this detonation wave starts is enormously great; hence any solid particles present in the tube will be heated to a high degree of incandescence. We have, therefore, a wave of intense light traveling through the tube. At the same time we have a wave of high compression traveling through the tube in the opposite direction. The gases in the forward part of the tube have perhaps not completely finished their reaction. As the wave of high pressure goes through the reaction mixture in the backward direction it increases the concentration of the reacting substance and, therefore, increases momentarily the rate of reaction, the heat development and the incandescence. The result is that we have two bright waves traveling in opposite directions.

These waves traveling through the tube, that is, the detonation waves, are of extraordinary interest to the chemist. They have been used to show, in many cases, that reactions which seem to go on in one stage really are complex. I intended to discuss some of the purely chemical results obtained by studying the explosion waves in certain mixtures as an illustration of what can be done with a phenomenon of that sort, but unfortunately I have not sufficient time to do it.

I have been talking thus far about an open tube: again I have greatly simplified the situation over what it is in an automobile. Suppose now that we have a tube closed at both ends and that the reaction starts at one end. The flame travels, let us say, slowly up to a certain stage, and then the period of rapid progress, namely, the detonation stage develops. The detonation wave traveling forward hits the end of the tube and is reflected back. The retonation wave strikes the other end of the tube and is reflected back in the opposite direction. Those two waves are bound to meet and they will affect one another in various ways, depending on the place in which they meet. The problem becomes very complicated. It is further complicated by the fact that under different conditions the point in the tube at which the detonation wave starts also varies. For example, the flame may go almost all the way through the tube before the high velocity necessary for the detonation is reached. Then what will happen? The detonation will start and immediately be reflected back, traveling simultaneously with the retonation wave through the tube in the opposite direction. In other words, we can have a wave of approximately twice the magnitude of the ordinary detonation wave.

Now, when we consider that the ordinary detonation wave travels at a velocity of about 1 mile per sec. in certain gases, and that the pressure developed momentarily, not, of course, the pressure throughout the whole tube but the pressure in the wave-front, may be as as high as 1000 lb. per sq. in. and that under certain circumstances we may sum up two waves of that sort, we can see what enormous local pressures may result from so simple a phenomenon as merely starting a gas burning in a closed tube. We can see how greatly the character of the waves in the tube may be influenced by the point at which we start the burning of the gases. But in an automobile-engine cylinder the thing is even more complicated, because not only are the gases not at rest, but are moving about so as to interfere with those waves; we have a moving piston passing back and forth through the cylinder; and we have a third kind of wave starting at the point of the spark plug, that is a momentary wave of compression and rarefaction, that is, a real sound wave. The sound wave will travel more rapidly than the flame. It may hit the walls and be reflected back. The result is, as we can see from Dixon's work, that the flame may have a peculiarly curved shape caused by the impact of sound waves upon the detonation wave itself.

I would like to have had time to carry this idea over into some work that has been done recently on detonation by automotive engineers. I know of that work merely as it has been described in the literature, and I must confess that I have not had much time to go into that literature. The work of Dixon has been most admirably complemented by the work of Woodbury and the studies of Midgley and other engineers in the automotive field. I do not know all the work that has been done on turbulence and detonation, on explosion waves and other phases of the subject; with the marvelous facilities that these men have at their command, they have accomplished remarkable results in the years they have been working on it. As a result of this work there has been considerable discussion in the automotive journals on the economy that could be effected in the use of gasoline by increasing the compression, and the difficulties that increased compression meets with in certain substances.

Theories Concerning Knock

There are three theories, so I understand, about knock. One is that it is caused merely by the mechanical impact of metallic parts. So far as the theory is concerned, we might as well say that knock comes because something knocks, for, so far as I can see, that is all that that theory amounts to. It does not say why the parts impinge upon one another at certain times and not at other times.

Another theory is that there is spontaneous ignition and a simultaneous development of pressure throughout the cylinder. Objection has been raised to this theory on the ground that substances like carbon disulphide, which have a very low ignition-temperature, do not tend to produce a knock in an automobile engine. That sounds like a good objection.

The third theory, the one that appeals to me most, is that knock is a result of the development in the cylinder of a detonation wave, a wave in which we have large differences of pressure in the wave-front; that these high pressures that exist at the moment of the forming or passing of the detonation wave through the cylinder cause deformations in the cylinder and give rise to vibratory motions that produce sound. This theory sounds extraordinarily attractive and particularly so in view of the work that has been done on knock preventives. As you all know, Midgley has reported on a number of substances that decrease the tendency to knock when they are introduced into the fuel. Midgley's explanation is that these substances are negative catalysts. They are substances that decrease the reaction velocity of the burning fuel and, therefore, since they decrease the reaction velocity, they decrease the acceleration in the flame, so that the acceleration is not sufficiently great to develop the detonating speed before

the combustion is complete. I will not discuss it because it has been described[3] and because you are undoubtedly familiar with it. It occurred to me, however, that it might be desirable to attempt to formulate some other hypotheses to explain the action of knock preventives, to illustrate to you that theoretical discussions of a topic like this may lead to ideas of practical value. I feel at liberty to do this even though the hypotheses, on account of my lack of familiarity with actual conditions, may be impossible; my purpose will be accomplished if I can show that this theoretical discussion can lead to experimental work.

If knock is produced by detonation waves, then knock prevention must be accomplished by altering the conditions within a cylinder so as to prevent the initiation of detonation waves. The latter will occur only when the reaction velocity at some point within the cylinder exceeds a certain critical velocity. Maintaining as low a temperature as possible is of course the first thing that one would think of and its importance is well known. But I wish to speculate particularly about the substances that are knock preventives and not about the phenomenon in general. The question that is to be answered is: How can certain foreign substances keep the reaction velocity from exceeding the critical value to which I have referred? The answer that Midgley has given is that of negative catalysis; it seems to me to be worthwhile, as a sort of concrete illustration of my talk, to attempt to see whether there may not be some other possibilities.

The first one that occurs to me is just the opposite of Midgley's. It is not a very satisfactory one, but it is of interest because it illustrates how one can reach the same conclusion by totally different paths. One way of preventing the reaction in the cylinder from becoming too rapid would be to have the reaction wave pass through partly burned gas. If, therefore, we can cause the gases in the farther end of the cylinder to react partly, before the flame reaches them, we may be able to prevent the formation of an explosive wave. This partial burning of the gases at the end of the cylinder might be brought about by the practically adiabatic compression produced by the combustion of the gases near the spark-plug. To make this kind of preignition possible, the ignition temperature of the mixture would have to be lowered to a point at which the heat of compression could cause appreciable but relatively slow chemical action to occur at some distance ahead of the actual flame. On this basis we should account for the effectiveness of knock preventives by assuming that they act as positive catalysts and thus lower the ignition temperature to the required point. The objection to this sort of hypothesis is that there appears to be no relationship between the ignition temperature of a fuel and the tendency of the latter to knock.

Another point of view to which one is led by considering Midgley's experiments in the light of the theory of reaction velocity is one that is very nearly the same as Midgley's—namely, that the knock preventives are catalyst poisons instead of negative catalyzers, as Midgley calls them. According to the hypothesis of catalyst poisons, the walls of the cylinder and the head of the piston, the spark points, the valve materials and other portions of the apparatus in contact with the fuel mixture, ordinarily act as positive catalysts, thus accelerating the combustion until it reaches the stage of detonation, and the function of the knock preventive is to be absorbed on these catalytic surfaces so as to prevent their accelerating influence.

I suppose you practical men are saying to yourselves: "There is the typical university professor, quibbling about words, making a big fuss about changing the term 'negative catalyst' to 'catalyst poison.'" But I can show you that the difference is not merely a quibble, that it is a real difference capable of experimental study. And if the ideas that I am presenting lead to a new experiment, they will have more than fulfilled their purpose, because my knowledge of the automobile is too elementary for me to be able to help solve any of its problems. If anti-knock materials are catalyst poisons to catalytic surfaces in the cylinder wall, they must be deposited in some way. Because of the motion of the piston and the violence of the explosions these deposits could not, of course, persist for long, but they ought to persist for an appreciable length of time. If that is true, after the use of a knock preventive there should be a period of lag, during which untreated fuel should not cause knocking; and I should expect that this period of lag would last longer than the time required to sweep out the residual anti-knock material. At all events this hypothesis is capable of experimental verification. Of course, if it should be demonstrable that anti-knock materials act as catalytic poisons, one would be strongly tempted to try to poison the cylinder, piston and spark-plugs permanently and thus avoid the use of a knock preventive.

The idea that these substances might be catalyst poisons is suggested by their chemical character. You will recall that, in general, organic amines are not very bad poisons for catalysts. They give the catalyst only a slight feeling of discomfort. The amines, likewise, have but slight effectiveness as knock preventives. Iodine compounds are more serious poisons; they are also better knock preventives. Arsenic and sulphur compounds are more effective than iodine compounds in both ways. But the worst catalyst poisons and the best knock preventives are lead compounds. Likewise, the amount of material required to poison a catalyst is about the same as that which acts as a knock preventive. The parallelism seems worthy of further thought. If I have succeeded in showing the importance of some of the fundamental chemical theories to the practical automotive engineer, I shall feel well satisfied, even if these suppositions which I have dignified with the name of hypotheses seem far fetched and impossible to the man who is in closer touch with the realities of the gas engine than I am.

THE DISCUSSION

H. L. Horning:—I was very happy to hear Professor Schlesinger refer to Dr. Dixon of Manchester University, because I had the honor of connecting up the apparatus with which Dr. Dixon made his classic experiments that showed the relation between the phenomenon of detonation in a cylinder and detonation in a tube. I told Dr. Dixon of our experiences with pressures in the cylinder. He dug out a dust-covered manuscript, and we heard, for the first time, the connection between the knock in the cylinder and the phenomena that he had demonstrated so well years before. I felt very much abashed to think that the man who had prepared that paper in 1892 should be telling us at this late date what was happening. Dr. Dixon wrote the equation and explained to me the action of carbon monoxide and water vapor. We have definitely settled and controlled the tem-

[3] See The Journal, June, 1922, p. 451.

perature of the piston, the surface of which is the largest and most actively catalytic surface in the cylinder because of its temperature. By doing so we have been able to run the compression up, and this has enabled us to get greater economy.

It is interesting to me to see that when the temperature is increased suddenly a point is reached where things happen. I believe it was one of our factory men who first found out what knock is, that is, what causes it. He called my attention to a little washer lying on top of the cylinder that jumped every time there was a detonation. We were producing as high a detonation as we could in the engine. We put the washer on each of the four cylinders and it jumped the highest on the cylinder that knocked. I leveled my eye along the cylinder and actually saw the head of the cylinder bulging under the knock; you can do it if you get the detonation high enough. We believe this was one of the earliest times, if not the first, that the knock was seen.

Dr. H. C. Dickinson produced an instrument at the Bureau of Standards in which he utilized this principle, and Midgley's knock indicator, a very accurate instrument, is also a development of it.

The fundamental reason for trying to get turbulence is to dig that stagnant layer off the wall and get it into the mixture. There is a temperature-drop of something like 1000 deg. cent. (1800 deg. fahr.) between a point 1 mm. (0.03937 in.) inside the surface and the surface of the cylinder. The stagnant gas layer is one of the great problems that steam engineers have to deal with. We who have to do with the chemistry of combustion have the problem of getting that layer off the surface.

We have controlled the knock, first by reducing the surface, as Professor Schlesinger has mentioned, by reducing the deposition of carbon and by keeping the temperature down; and those are all the elements that have been mentioned. We prevent detonation by having a very compact combustion-chamber so that the flame will not have a long run. We do not allow it to be a tube; we make it as nearly spherical as we can. I think we made at least 100 cylinders before we got a shape that met all the requirements.

We know that it is not possible to make a piston of iron and keep the critical temperature of the center of the piston below the temperature at which Red Crown commences to "kick up." There is only one set of substances that will do it and that is the aluminium-magnesium series. Whether putting on a poison surface will act permanently, I do not know, but it is a very attractive theory.

A catalyst might be likened to the marriage ceremony. A catalyst is to chemical reaction what a priest is to marriage. He is very necessary and when it is over he is good for another marriage and good for an indefinite number of marriages, the only effect being a general wear and tear.

We have controlled the temperature of the surface; we have controlled the relative shape of the mass and the distance from the spark to the remotest part of the combustion-chamber; those are all things that Doctor Schlesinger has mentioned and our experiments have borne out his theory.

R. E. WILSON:—I have been much interested in what Doctor Schlesinger has said, and I think his explanation of the fundamentals of reactions, particularly of gaseous reactions, will be extremely helpful. Probably everyone who has been in touch with Midgley's work has a pet theory of detonation and of how anti-knock works. One of the favorite indoor sports is writing down the series of anti-knocks and finding parallels with other properties; and there are many such parallelisms. Professor Schlesinger has pointed out a new and interesting possibility in showing that most anti-knocks are catalyst poisons, and suggesting that they may act as anti-knocks by depositing on the walls of the cylinder and destroying their catalytic activity, which is assumed to be the cause of the acceleration in flame velocity that results in detonation.

On consideration, however, there appear to be several serious objections to such a theory. In the first place, the parallelism is not complete; mercury and sulphur are powerful catalyst poisons, yet exert no anti-knock effect; indeed, they are, if anything, slight knock inducers.

Again, Doctor Schlesinger pointed out that according to his hypothesis there should be a period of lag in the action of anti-knock. I have seen an engine switched from one fuel to another a great many times and can certify that with a short feed tube the period of lag is not more than 10 or 12 revolutions of the engine, a comparatively short time considering the fact that there is always a little liquid in the carbureter that contains some of the old catalyst. Knocking tends to increase with time, but this is because a knock increases the temperature in the cylinder, so that when the condition that produces a knock is changed, the first knock is never so hard as the second or the third. Possibly the absence of a period of lag might be due to the fact that the piston would quickly scrape off any deposit on the cylinder-walls if it were not being constantly renewed, but it should be pointed out that the walls that are scraped off by the piston are covered with a thin film of oil and would hardly be expected to be active surfaces compared with those of the piston and the cylinder-head, which generally are at a higher temperature and, of course, are not scraped off. If these surfaces were catalysts, we should, therefore, expect to find more of a lag than actually occurs. I will not say there is no lag, but the lag is extremely small. Furthermore, it might be pointed out that detonation will take place in a glass tube and a glass surface would certainly not be expected to have the same catalytic effect as the metallic surface in the engine. Flame-fronts, as I recall, show a bulging at the center. This would not indicate that the reaction was being catalyzed by the surface and that the surface was the fundamental cause of the increase of speed. In the light of these facts, it seems almost certain that detonation takes place in the gas phase rather than at the surface.

One significant fact with regard to anti-knock materials is that some lead compounds work and others do not. The critical thing appears to be whether the compound is completely vaporized at the temperature that exists just before the explosion. It appears that the anti-knock must be in the molecular or vapor state before the explosion in order to do any appreciable good.

My own theory of knock is along the line that Mr. Horning has mentioned, that is, what might be called the radiation theory. Is it not reasonable to assume that when the flame moves through the cylinder it is sending out radiations ahead of it? It must be so. These radiations would probably have a very marked influence on the gas. We know that ultra-violet rays will greatly accelerate reactions; a wave-length below ultra-violet might have a still more marked effect. Is it not conceivable that the flame may be sending ahead certain activating radiations that either split up hydrocarbon molecules, ionize the oxygen, or in some other way bring

the mixture into a state in which it will burn much more rapidly than it would ordinarily? The function of an anti-knock then becomes the absorbing of these radiations; and we then see how a very small number of anti-knock molecules can affect the behavior of a large number of other molecules. If the radiations can be absorbed almost as soon as they start, they will not do nearly so much damage as the radiations that go into the volume of gas in front of the flame. So it seems to me that something of this description would come nearest to accounting for all the known facts. Unfortunately, as Midgley points out, this theory is very hard to prove or disprove. If we make measurements in a particular part of the spectrum and find nothing, all we can do is to postulate radiations in another part of the spectrum; and we should have to find a way to measure that part. In other words, the theory is extremely difficult to test out, and in that respect is not so helpful as Doctor Schlesinger's.

DR. H. I. SCHLESINGER:—I am not at all displeased to hear Mr. Wilson's statements about the lag. I want to point out that what I was talking about was not really preignition but rather spontaneous ignition after the flame had developed in one portion of the cylinder.

O. B. ZIMMERMAN:—Unquestionably a large amount of work can be done in coordinating the theories advanced by Professor Schlesinger with the practical applications we are endeavoring to carry out. The net result must be progress, must be helpful in producing effects that we have not been able to produce to date. I feel certain that by such applications the efficiency of the internal-combustion engine will be increased eventually far beyond what it is today. We can state roughly that the average automobile engine that is operated under the crude methods of applying chemical science to mechanics at the present time, has an efficiency of perhaps 15 per cent. We have seen Diesel engine data that bring that up to perhaps 39 per cent at the maximum, but we have still a long way to go before we shall attain 50 and 60 per cent in the ultimate by applications such as have been mentioned. I am confident that we can treat fuels before they go into the cylinder, possibly through catalytic action, and produce gases that will give us better results than we are getting today by transmitting them through a carbureter in the true vapor form.

Perhaps I have made an overstatement, but I feel that we have not worked out all the possibilities in our methods of operating on liquid fuels today. I think we are doing very well, but we have not applied all the possibilities so far as design or the use of science is concerned.

MR. HORNING:—To show the progress that can be made, a Ford engine has a relative efficiency of 46 per cent against 70 which it should have. By merely changing the head and the piston, it could be brought to 64 per cent. It is only a matter of design. You are entirely right in your statement.

MR. HULL:—Would it not be possible to dissolve anti-knock material, the catalyst poison, in lubricating oil instead of gasoline, to get a film on the cylinder-walls, and save some dope, yet have the same effect?

DR. SCHLESINGER:—The question of introducing material into the cylinder is one that most makers of automobiles can answer better than I can. If the catalyst poison has to be in the gas to absorb the radiation, it should not be so effective when it is introduced in the lubricating oil. If it has to be on the walls, it might be more effective if it were introduced with the lubricating oil. I do not say that this is necessarily true, because the possibility of getting at the walls is very great even if a film of oil is there, particularly if the material is oil-soluble.

If I were to answer the objections that have been raised to what have incorrectly been called my theories, I think I should be contradicting myself. I presented them, not as an expert on the automobile, but, as I have already repeatedly said, simply to show how a fundamental study may lead to hypotheses that may be verified experimentally or disproved; and I maintained in the discussion that, after all, any hypothesis has value only so far as it leads to experiment and to further thought on the subject.

The hypothesis that I have presented here I have presented with trepidation, because I do not wish to be put on record as saying, "Here is a theory that will solve all the problems of the automotive engineer." It has been presented merely as an illustration of the type of thought that comes logically from a theoretical viewpoint of the subject. It has not been presented as the mature thought of an experienced automotive engineer.

CHAIRMAN T. MILTON:—It is becoming apparent that Doctor Schlesinger is attempting to function more or less as a catalytic agent to stir up a little reaction among the turbulent Hornings and Wilsons and get them to produce something. I think if he has been successful in doing that he has accomplished a great good for the Society.

MOTORSHIPS

THE tonnage of vessels now building in the world, which are to be fitted with internal-combustion engines, amounts to 923,738 tons, while the tonnage of steam vessels under construction is 1,530,884 tons. The motor tonnage, therefore, equals over 60 per cent of the new steam tonnage.

In Denmark, Germany, Holland and Sweden the motor tonnage under construction greatly exceeds the steam tonnage, the combined total for these countries being 142,828 tons of steamer and 477,000 tons of motorships. The world figures include 84 motorships between 5000 and 10,000 tons, 7 between 10,000 and 15,000 tons and 6 between 15,000 and 22,000 tons.—*Lloyd's Register.*

Some New Electrical Instruments for Automotive Research

By J. H. Hunt[1] and G. F. Embshoff[2]

Cleveland Section Paper *Illustrated with* Photographs and Drawings

ABSTRACT

ELECTRICAL instrumentation for research work has been developed to a high degree because of the great speed of action and the convenience of application of the electric current. The current serves to transmit instantly to a recording instrument the impulses imparted to it by a detecting device. There is available a great wealth of indicating, integrating and recording devices that can be used readily for automotive research by the aid of auxiliary devices, some of which can be purchased and some of which can be easily made in any ordinary model shop or toolroom. In the study of automotive mechanism the research engineers have drawn upon the investigation work of men in other lines of industry and have found it necessary to go back of these men to the scientific investigators who are attacking the elements of various problems in the physical and chemical laboratories.

The authors of the paper describe a number of instruments recently developed for measuring and recording engine-cylinder pressures, detecting and recording crankshaft and camshaft vibrations, and detecting the sources of noise and measuring the intensity of noise vibrations.

The problem in devising such apparatus is to find an electrical device that will supply current, voltage or frequency that is proportional to and caused by the quantity it is desired to measure and then to select some instrument to go with it, using a standard article whenever possible. This paper has great value because it describes the elements that have been found best suited for the desired purposes and shows how the detecting, measuring and recording elements are combined into complete, practical working instruments. The authors also tell how the instruments are calibrated and used and explain the characteristics of diagrams made with them.

RESEARCH is a matter of measurement and analysis. In the usual investigation the two operations proceed concurrently, a new measurement requiring revision of the previous analysis and the revised analysis pointing to the need of new measurements. Improved instrumentation usually leads to new results, by permitting either more accurate measurements or measurements under new conditions. It is commonly found that after a problem has been solved the successful investigator has so arranged his study that he has been able to make a new and proper evaluation of the controlling factors. To do this, new instruments have been used or new methods of using old ones have been put into effect.

Because of the speed of action and the convenience of application of the electric current, electrical instrumentation has been developed to a high degree. A great wealth of indicating, integrating and recording devices is available. These instruments can be used readily for automotive research by the aid of auxiliary devices, some of which can be purchased from several sources of supply and some of which can be made easily in any ordinary model shop or toolroom.

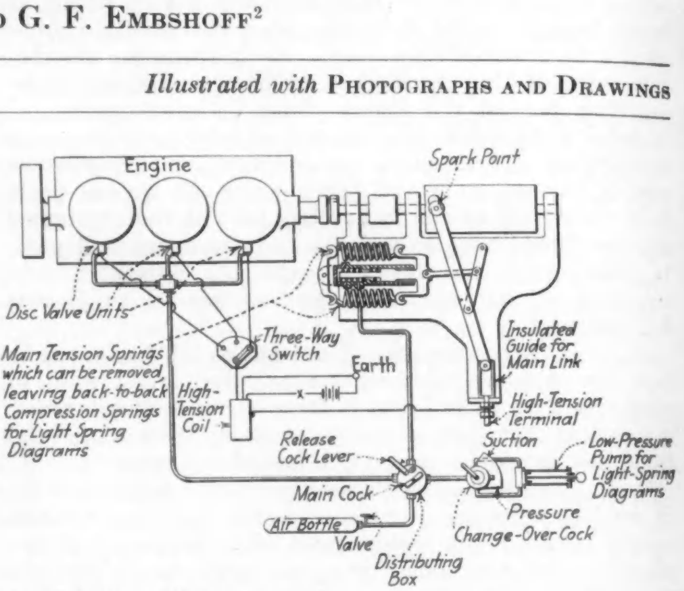

Fig. 1—Diagram of Farnboro Indicator on Multicylinder Engine
Pressure in the Cylinder Is Balanced against Pressure from an Air Bottle on a Small Valve Whose Movements Break the Primary Circuit of an Induction Coil. The Spark from the Secondary Circuit Strikes Through Recording Paper at the Spark Point to a Cylinder Driven by the Engine. Readings Are Taken at Any Point Where the Pressure Balance Changes Instead of at Some Definite Point in the Revolution. The Device Permits a Complete Record To Be Taken in a Very Short Time

The electric current, when used with electrical instruments, serves to transmit to an indicating or recording device of proper characteristics the impulses that are supplied to it by a detecting device. The problem is to find an electrical device that will supply current, voltage or frequency proportional to and caused by the quantity it is desired to measure, and then to select some instrument to go with it, using a standard device whenever possible. A familiar example is the ordinary thermocouple installation for reading temperatures. Heat supplied to the couple generates a voltage that can be read by a potentiometer or a galvanometer conveniently placed. The voltage has a definite relation to the temperature at the couple. When using it, we have only to make sure that the temperature of the thermocouple is the same as the temperature of the body to be measured and to be sure of the calibration under the conditions of the installation.

Recording Indicator for Cylinder Pressures

A recent application of electrical methods of transmitting and recording information is found in the Farnboro engine indicator[3] shown diagrammatically in Fig. 1. Pressure within the cylinder is balanced against pressure supplied by an air bottle on a small metallic valve which can move a few thousandths of an inch from one seat to another, breaking the primary circuit of an induction coil in so doing. The spark from the secondary strikes through recording paper to a cylinder driven by the en-

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[2] Research engineer in the electrical division, General Motors Research Corporation, Dayton, Ohio.

[3] See *The Automobile Engineer*, January, 1925, p. 9.

gine. The device is thus a step-by-step indicator, readings being taken at any point where the balance changes instead of at some definite point in the revolution, as in the Bureau of Standards indicator. The circuit diagram shown is taken from the makers' catalog.

Such a device permits a complete record to be taken in a very short time, as the use of electric currents to detect the point of balance, transmit the information and make the record permits working at very high speed. Use of the electric currents also allows great flexibility in the location of the recording device with respect to the opening into the cylinder where the pressures are measured, without error due to inertia of connecting mechanism or any difficulty in providing space for these connections.

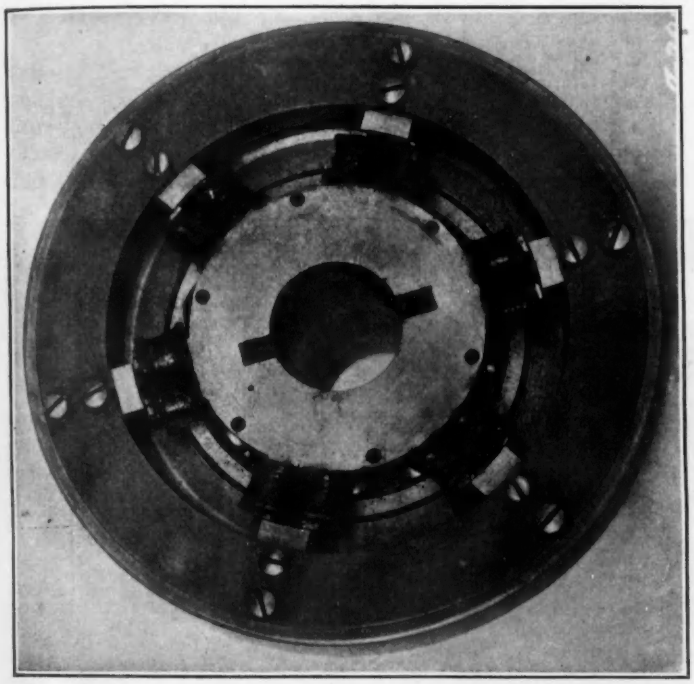

Fig. 2—Detector for Measuring Torsional Vibration

This Depends for Operation on the Change of Flux Due to Relative Motion between a Magnetic Circuit and a Winding. A Small Flywheel Is Carried on the Shaft To Be Studied and Is Driven Through Weak Springs So That It Tends To Rotate at Uniform Speed. When the Engine Shaft Does Not Turn at Constant Speed, There Is Relative Motion between It and the Flywheel of the Indicator. The Outer Ring of the Flywheel Is Carried on Ball Bearings on the Hollow Hub and Has Poles Projecting Radially Inward That Are Magnetized by Magnets of Cobalt Steel. On the Hub, Adjacent to Each Outer Pole, Are Two Inner Poles, Both Wound. Movement of the Inner Poles to Either Side of the Center of the Outer Poles Transfers a Small Amount of Flux from One Pole to the Other and the Electrical Change Is Recorded by an Oscillograph

Detector for Registering Torsional Vibration

Measurements are frequently desired on the torsional vibrations of crankshafts and camshafts. Such measurements should include not only frequency and amplitude but also the phase relation of these vibrations with respect to the engine cycle and with respect to the vibrations in other shafts. All of these measurements can be made by the oscillograph described in Appendix 1, providing a suitable detector of the vibrations is available. If a small flywheel is carried on good bearings on the shaft to be studied and driven by the shaft through relatively weak springs, this flywheel will tend to run at uniform speed, and relative motion between the flywheel and the shaft will arise whenever the shaft is not running with uniform angular velocity. Relative motion between a magnetic circuit and a winding is the basis of all electrical generators, and we can make a detector of these

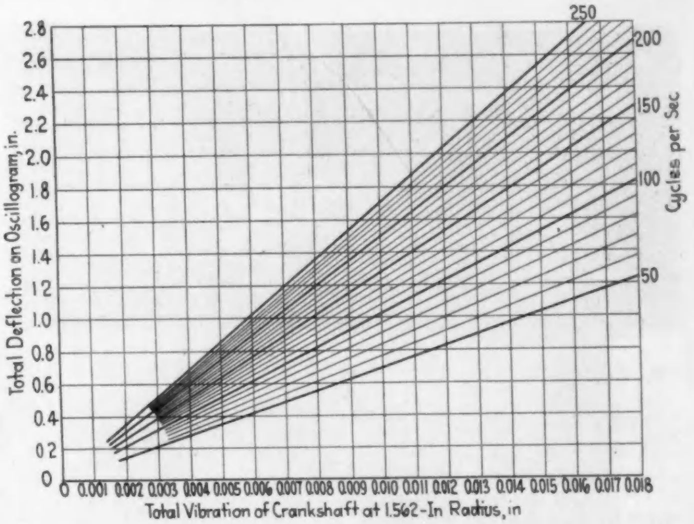

Fig. 3—Calibration Chart of Torsional-Vibration Indicator and Oscillograph Element in Combination

Deflections Increase with Frequency as Well as with Amplitude of the Vibrations. The Rate of Flux Change Is Doubled by Doubling the Frequency at a Given Amplitude. Calibration Is Carried Out by Holding the Outer Flywheel Rigid and Oscillating the Inner Hub by an Arm Driven by an Eccentric of Known Throw

relative motions by mounting the main parts of a small generator magnetic circuit in the outer flywheel, where the parts will contribute to the inertia, and by mounting windings on the shaft, within which windings voltage is generated by the flux change. It is highly desirable to design the magnetic system in such a way that the total flux change for different amplitudes of the motion is proportional to the total motion.

Fig. 2 shows an instrument that has been developed with these requirements in mind. The poles projecting radially inward are magnetized by short circumferentially-placed magnets of cobalt steel of high coercive force. Below each outer pole are placed two inner poles, both wound. All pole corners are sharp and the inner poles overlap the corners of their outer poles equally. Moving the inner system to either side of the center transfers a small amount of flux from one pole to the other, the rate of transfer being uniform until the side of one inner pole lines up with the side of an outer pole. The range of vibration on which the device can be used is thus determined by these dimensions.

The outer magnet system is carried on two ball bearings mounted on the hub that carries the inner system, including the wound projecting poles. In using the instrument the inner system is clamped rigidly on an extension of the shaft to be studied. Brass slip-rings are

Fig. 4—Record from Six-Cylinder Engine at 1600 R.P.M., Full Load

The Chart Reveals That There Are Three Vibrations of the Crankshaft for Each Firing Stroke and That the Disturbance Caused by Firing Cylinders Nos. 1 and 2, Which Are Farthest from the Flywheel, Is Greater than the Distortion Caused by the Other Cylinders

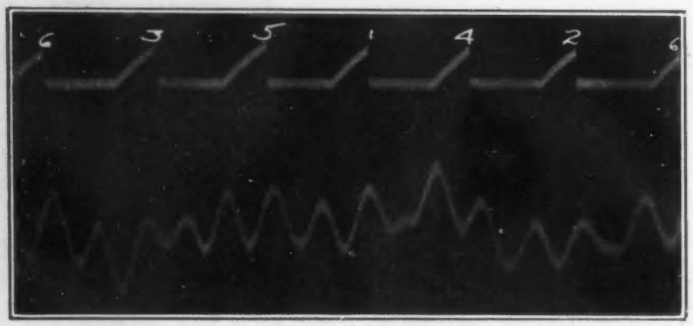

FIG. 5—RECORD FROM SIX-CYLINDER ENGINE AT 2000 R.P.M., FULL LOAD

Although the Effects of Cylinders Nos. 1 and 2 Are Greater than Those of the Other Cylinders, the Succeeding Cylinders Do Not Fall into Step with the Crankshaft Period and the Amplitude of Vibration Is No Greater than at the Lower Speed

carried on the hollow shaft of the device and are connected to the windings. When taking current off, these rings are coated with mercury amalgam, as are the tips of the brass or copper strips serving as brushes to take away the current. By this means the contact resistance can be kept sufficiently uniform to avoid interfering with obtaining a proper record.

Our first instrument was made up for current excitation instead of using permanent magnets, but variation in resistance in the slip-ring contacts caused voltages to be generated that had no relation to torsional vibration and therefore vitiated the results. Proper design of parts and of voltage in circuit, winding resistance and contact resistance might make current excitation possible but is not to be recommended, as the permanent-magnet design is entirely satisfactory. The proportions of the detecting circuits are such that any variation of contact resistance between the amalgamated rings and brushes has only a negligible effect.

The flywheel is driven from the central hub by flat springs. The natural period of oscillation of the flywheel about the central hub is about 7 cycles per sec., which is so far away from the periods of the shafts usually studied that damping becomes unnecessary, but the absence of damping must not be forgotten, since we can easily get into trouble when working with vibrations of very low frequency.

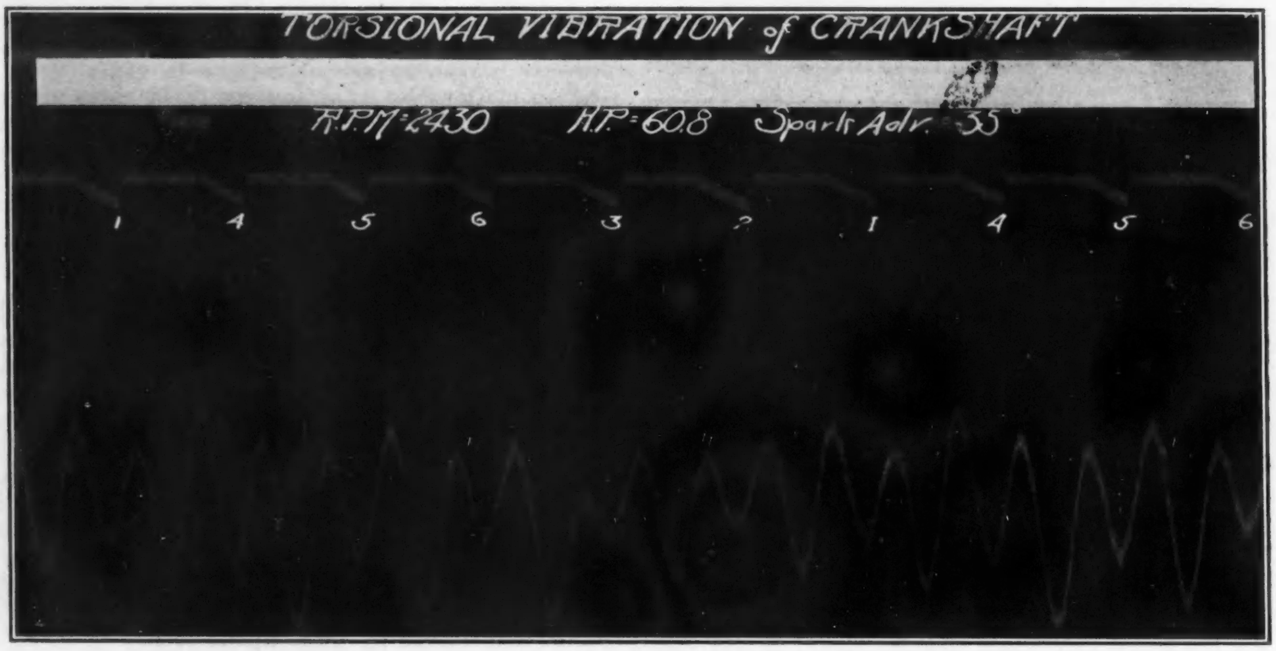

FIG. 7—RECORD FROM SIX-CYLINDER ENGINE AT APPROXIMATELY 2400 R.P.M., FULL LOAD

The Reduced Amplitude of the Vibrations Is Due to Changed Phase Relations that Develop at the Higher Speed. Even Less Sustained Vibration Becomes Evident at Still Higher Speeds

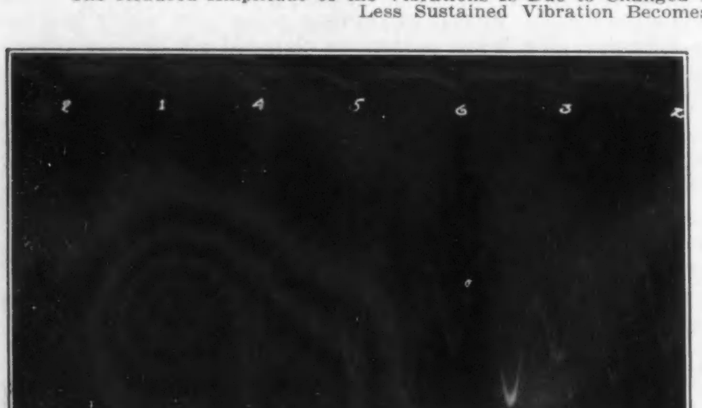

FIG. 6—RECORD FROM SIX-CYLINDER ENGINE AT 2400 R.P.M., FULL LOAD

This Reveals Two Vibrations per Engine Impulse and Much Greater Amplitude Than at 2000 R.P.M., as There Is Much Less Time for the Dying-Out of the Vibrations. This Is the Period for This Particular Engine That Is Likely To Be Objectionable to Passengers

WHAT THE CHARTS REVEAL

Fig. 3 is the calibration chart of the instrument and the General Electric oscillograph element in combination. Attention is called to the fact that the deflections increase with frequency as well as with amplitude, because the generator really measures rate of change of flux, not amplitude. The rate of change is doubled by doubling the frequency at a given amplitude. Eddy currents in the solid poles and inductance in the generator windings prevent the deflections for a given amplitude from being directly proportional to the frequency. Calibration is carried out by holding the outer flywheel rigid and oscillating the inner hub by an arm driven by an eccentric of known throw.

To get a complete analysis of a given vibration, when

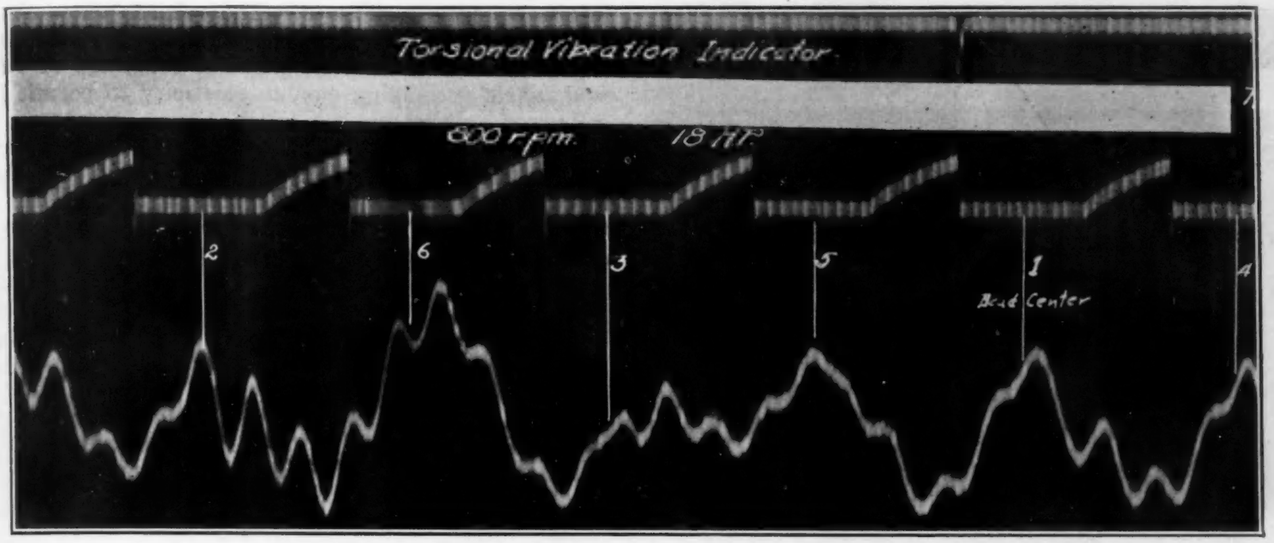

FIG. 8—RECORD TAKEN FROM A MORE FLEXIBLE SHAFT THAN IS COMMONLY USED TODAY
The Vibrations of Large Amplitude Are Due in Part to Deflection of the Shaft Under Load Torque, in Part to Deflection of the Coupling Between the Engine and the Dynamometer and in Part to Higher-Frequency Vibrations Due to the Natural Period of the Shaft

several frequencies are present, it would be necessary to analyze the wave into its components, determine the amplitude corresponding to each component, and then replot. For automotive work this is frequently unnecessary, as the essential thing is to determine the frequencies present and the point in the cycle where they are strongest, so as to get some idea of the cause and the steps likely to be necessary to cure the trouble.

Having transformed the non-uniform motion of the shaft into electrical impulses of a value suitable for recording by the oscillograph, the other elements of the oscillograph can be used to record other data regarding the engine, such as the primary current in the ignition coil and the time of the spark at a particular cylinder, so that we can know exactly how the vibrations of the shaft are related to the engine impulses.

In the record taken on a six-cylinder engine at 1600 r.p.m., full load, as reproduced in Fig. 4, two things are immediately evident; (*a*) there are almost exactly three vibrations of the crankshaft for each firing stroke of the engine and (*b*) the disturbance caused by the firing of cylinders Nos. 1 and 2, which are farthest from the flywheel, is noticeably greater than the distortion caused by the other cylinders. There is, furthermore, an evident tendency for the vibrations to die out between the exciting impulses.

The effects on the same shaft at 2000 r.p.m., full load, are shown in Fig. 5. While the effects of cylinders Nos. 1 and 2 are greater than those of the other cylinders, succeeding cylinders do not fall into step with the crankshaft, the amplitude is not any greater than at the lower speed and the audible effects are less.

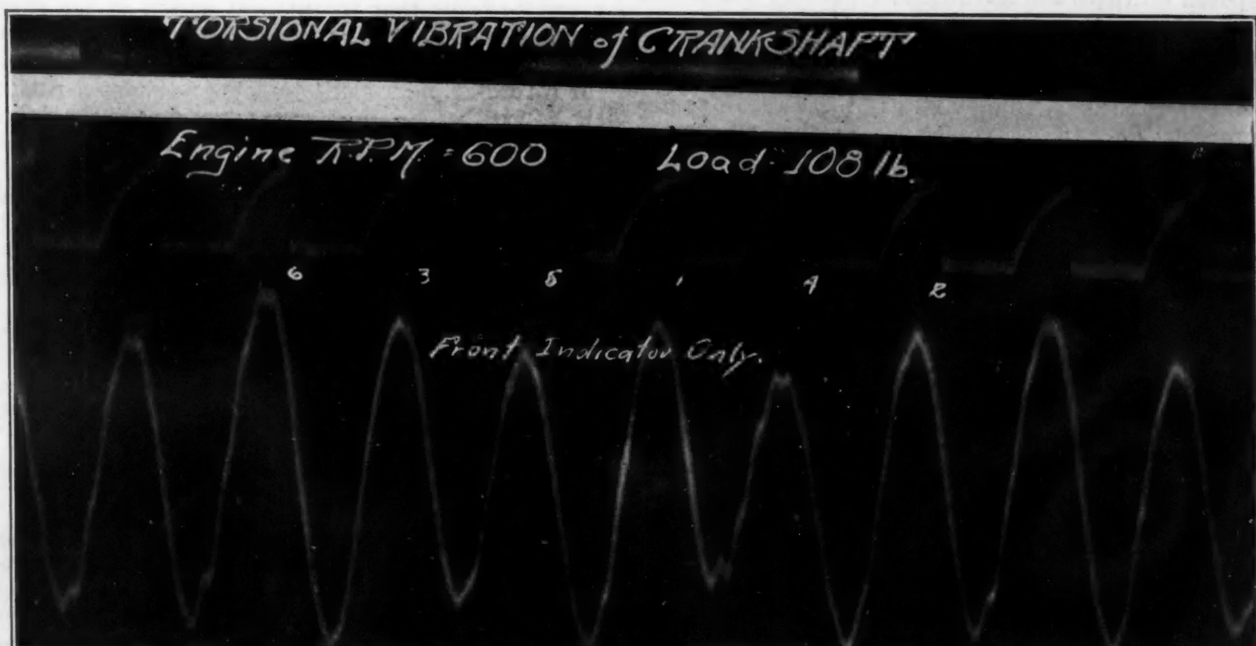

FIG. 9—DIAGRAM FROM FRONT END OF SHAFT AT 600 R.P.M.
This and the Diagrams in Figs. 10 and 11 Were Taken To Demonstrate the Reason for the Large Amplitudes Sometimes Observed at Low Speeds. They Show That the Deflections Are Due to Torque-Reaction Effects between the Engine and Dynamometer, the Elasticity of the Coupling Permitting the Building-Up of an Appreciable Oscillation

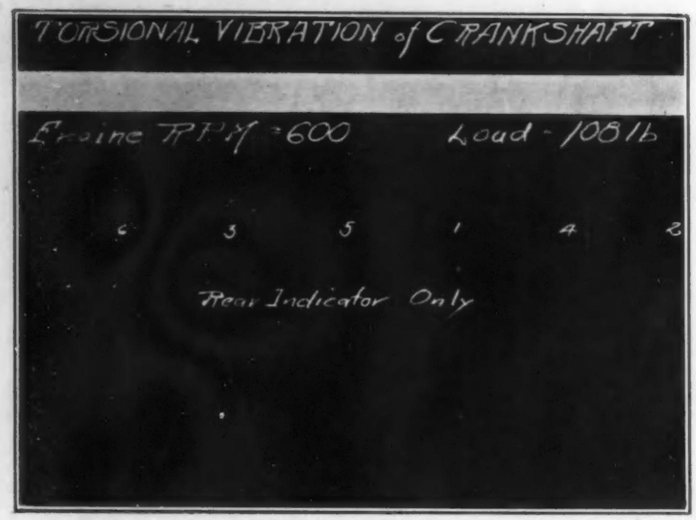

FIG. 10—DIAGRAM FROM REAR END OF SHAFT AT 600 R.P.M.
This Was Taken Simultaneously with That Reproduced in Fig. 9 and with an Identical Indicator Mounted in a Bell Carried on the Engine Flywheel

Fig. 6 reveals the conditions at 2400 r.p.m., at which speed there are two vibrations per engine impulse and, since there is less time available for the dying out of the vibrations, the amplitude is much greater. This is the period for this particular engine which is likely to be objectionable to passengers in an automobile in which it is installed.

The reduced amplitude due to changed phase relations which develops at 2500 r.p.m. is indicated in Fig. 7. Higher speeds show even less sustained vibration of the crankshaft.

The record reproduced in Fig. 8 shows conditions for a much more flexible shaft than is commonly used today. The vibrations of large amplitude that correspond to the period of firing are due partly to deflection of the shaft under the load torque and partly to deflection of the coupling connecting the engine to the dynamometer, while superposed on these are the higher-frequency vibrations due to the natural period of the shaft.

Records taken to demonstrate the reason for the large amplitudes sometimes observed at low speeds are reproduced in Figs. 9, 10 and 11. If these readings are not properly interpreted, confidence in the instrument

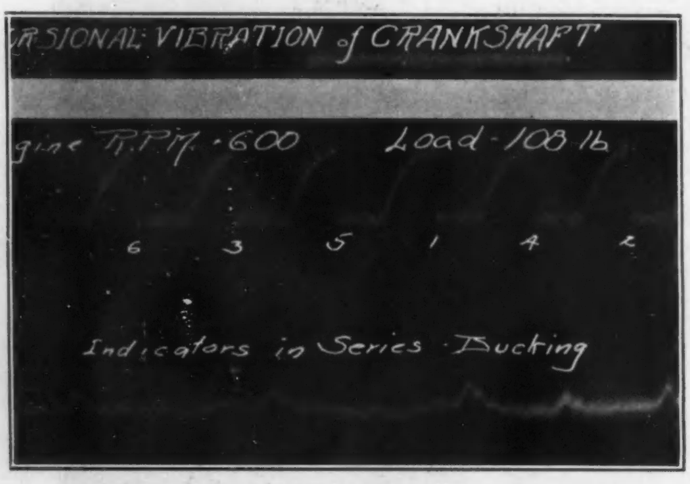

FIG. 11—DIAGRAM FROM THE TWO INDICATORS CONNECTED IN SERIES, WITH OPPOSING VOLTAGES
The Combined Effects Nearly Cancel Each Other, Showing That Torsional Deflection of the Shaft Is Only a Small Part of the Cause of the Non-Uniform Rotation

might be greatly reduced. The records show that the deflections are due to torque-reaction effects between the engine and dynamometer, the disc couplings of rubberized fabric possessing enough elasticity to permit building-up an appreciable oscillation.

Two identical instruments were used for these records, one mounted in front in the usual way and the other at the rear in a bell carried by the flywheel. Records were taken from each indicator and also from the two connected in series with the voltages opposing. The combined effects nearly cancel each other, showing that the shaft deflection is only a small part of the cause of the non-uniform rotation. The instrument was telling the truth about the situation but had no means of distinguishing between non-uniform motion due to shaft deflection and to oscillations between the inertias of the crankshaft and flywheel and of the dynamometer, the double coupling serving as the elastic element.

OTHER APPLICATIONS OF THE INSTRUMENT

An instrument of this type can, of course, be used on the camshaft. An example of a record taken on a chain-driven camshaft at an engine speed of 2450 r.p.m. is shown in Fig. 12. This is the speed for the particular engine at which the most pronounced crankshaft-period occurs. The effects at the camshaft are obvious. If desired, magneto generators could be fitted to the camshaft and crankshaft and simultaneous records taken.

Tests can also be made on shafts removed from the engine. Thus, if the shaft, clamped at the flywheel end and with the indicator mounted at the front end, is struck with a lead hammer on the No. 1 throw, a vibration is set up which will last several cycles, as the damping effect of the main bearings is eliminated. Such a test has been carried out to confirm a prediction we had made that the natural period of a four-cylinder shaft varied according to its position, because the throws can vibrate appreciably when vertical without moving the pistons and upper ends of the connecting-rods, while when horizontal any vibration of the throws must carry the pistons with it. We found in the case of a rather light shaft for a small engine that the natural period of the shaft was 230 and 290 cycles per sec. for the horizontal and vertical positions respectively. Obviously, it will be impossible for a four-cylinder shaft to show as sharp a period as a six, since the period changes from point to point in the revolution. This is of no practical importance in the four, since the vibration period due to one firing impulse for each third vibration comes at fairly high speed and the period corresponding to the pronounced period on the six is away beyond any possible speed in a commercial car. In the case of the eight-in-line, this condition may have more significance. One line-eight, using a shaft like two fours placed end to end and 90 deg. apart, is considered commercially smooth, although a vibration damper is not employed. Other line-eights, having the consecutive throws located 90 deg. apart, seem to require the fitting of a damper.

Summing up, we find that the instrument has the following advantages:

(1) Non-uniform velocities of a shaft can be measured in amplitude and phase relation with respect to the engine cycle
(2) Permanent records can be taken
(3) No appreciable change is made in the crankshaft period by the instrument itself
(4) Simultaneous records can be taken on crankshafts and camshafts

The disadvantages are:

(1) An oscillograph is required, limiting observations to dynamometer work

(2) The calibration varies with the frequency, requiring wave analysis preliminary to determination of the amplitude of the components

(3) Only rate of motion can be measured, making it necessary to derive the actual motion from the observed data

(4) Large total amplitudes cannot be measured without change in design

Tracing Noise to Moving Parts

Elimination of noise is a refinement in modern cars that is receiving increasing attention. Anyone who has done only a little work on the reduction of noise in a mechanism is impressed by the difficulty of using the sense of hearing to obtain reliable information. As a result, the amount of money that is spent to secure even a minor improvement frequently is appalling. Improved instrumentation will assist greatly in reducing the cost of such an investigation.

The ultimate objective in a noise investigation is to locate the source of the disturbance. It is frequently of great assistance in determining this to have measurements which determine the time of the noise with relation to the engine cycle and which can determine what particular element of the mechanism is giving out the most noise. Unfortunately, it is difficult to make such measurements on moving parts.

Choice of the proper detecting instrument can be assisted by considering the nature of noise. Generally, any noise or sound affecting a person is a disturbance of the air. In the case of musical sounds, the air is set in motion in waves of consistently repeating form, but when sound waves, as recorded, take the form of a ragged line that does not repeat itself in such a way that it can be resolved into a fundamental with higher harmonics, we have a noise. It is this type of sound that we usually have to deal with on automobiles, although sounds from gears and fans may be sufficiently uniform to approach the wave form of some sounds commonly considered musical when not too long sustained. Sounds come to the ear in air vibrations of exceedingly small amplitude. Lord Rayleigh stated that a vibration of an amplitude of 1.27×10^{-7} cm. would be audible to a normal ear. Such air vibrations are set up by vibrations of some part of an automobile. The relative amplitudes of the vibrations of different elements in the mechanism can be observed and measured if proper vibration-detecting instruments are available. The ordinary listening rod is an example of a crude device with which a skillful observer can obtain considerable information regarding the parts of a mechanism that are responding to a given vibration.

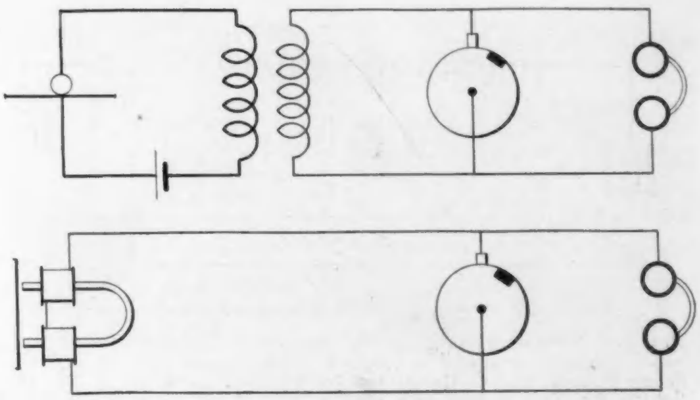

Fig. 13—Circuits for Converting Sound Vibrations into Electrical Impulses

The Upper Drawing Indicates a Telephone Transmitter Supplying Impulses to a Telephone Receiver Through a Transformer. A Metal Disc with an Insert of Insulating Material Is Driven by the Engine and Short-Circuits the Receiver during All but a Small Part of its Revolution. The Time of Sharp Sounds with Relation to the Revolution Can Be Determined by Finding the Disc Position at Which the Sound Occurs. The Lower Drawing Shows a Telephone Receiver Used as a Transmitter in a Similar Circuit

A simple method of timing a noise would be to convert the sound vibrations into electric currents of the equivalent wave form and then switch the connections in and out by a device synchronized with the engine rotation. The circuits in Fig. 13 show two possible ways of doing this. The upper drawing indicates an ordinary tele-

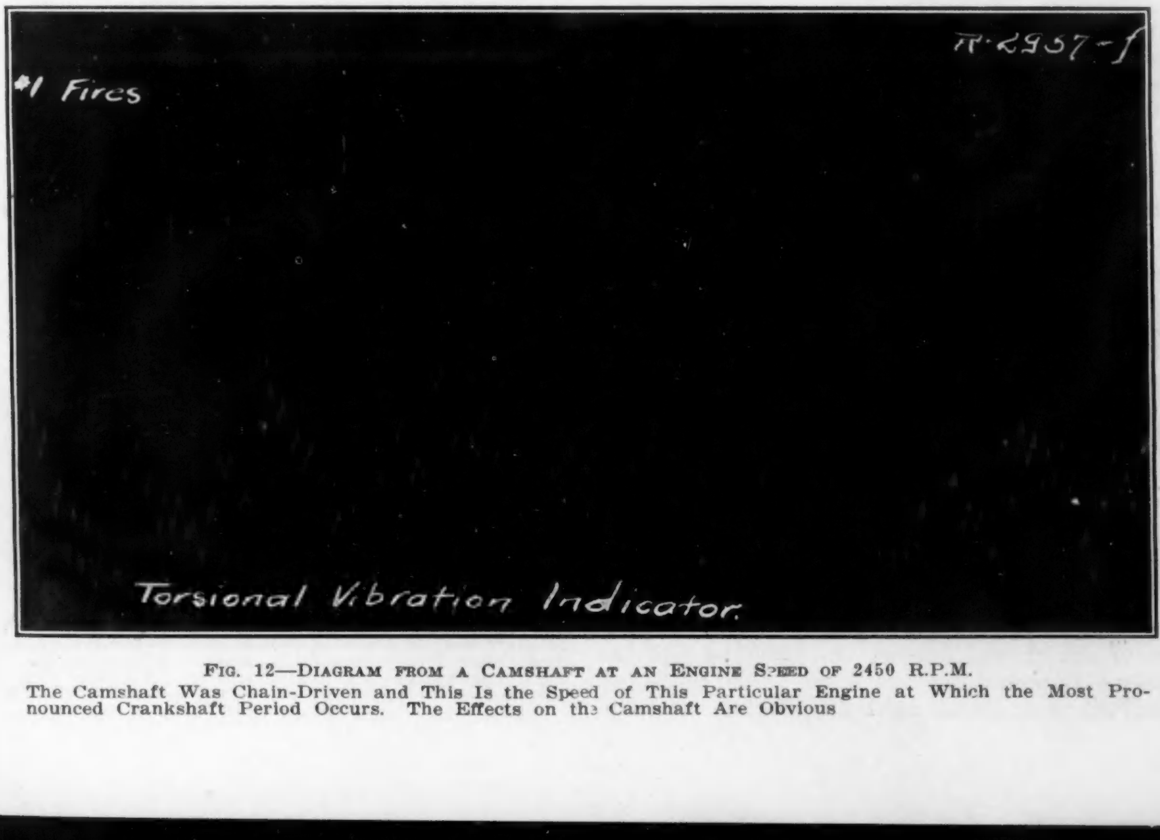

Fig. 12—Diagram from a Camshaft at an Engine Speed of 2450 R.P.M.

The Camshaft Was Chain-Driven and This Is the Speed of This Particular Engine at Which the Most Pronounced Crankshaft Period Occurs. The Effects on the Camshaft Are Obvious

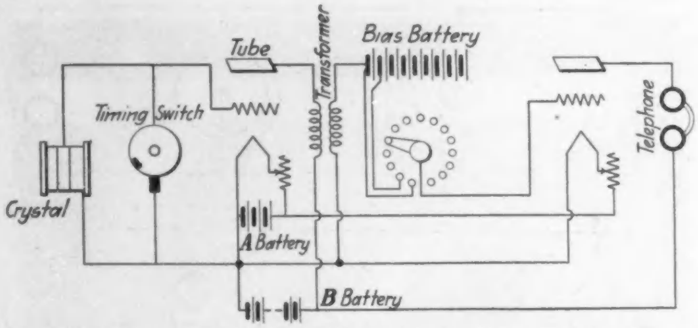

FIG. 14—DIAGRAM OF CIRCUIT FOR MEASURING VIBRATION INTENSITY

The Apparatus Includes a Rochelle Salt Crystal That Picks Up Sharp Sounds but Is Unaffected by Slower Vibrations, a Timing Switch for Determining the Time of the Noise with Relation to the Engine Cycle, an Amplifying Tube and a Transformer through Which the Impulse Is Transmitted to a Detector Tube with a Telephone in the Plate-Battery Circuit. A Bias Battery May Be Used, as Shown, If Only Coarse Readings Are Required. The Greater the Disturbance to the Crystal, the Greater Is the Impulse Carried to the Detector Tube and the Greater Is the Bias Voltage Required To Prevent This Impulse from Reaching the Telephone

phone transmitter supplying impulses to a telephone receiver through a transformer. A metal disc with an insert of insulating material a few degrees wide set in the periphery is driven by the engine or mechanism being studied and is connected so as to short-circuit the receiver during all but a small part of its revolution. So long as the sound being studied is sharp and stands out clearly from other sounds picked up, as is the case with pronounced piston slap of detonation, the time of the noise in relation to the revolution can be located accurately by finding the disc position at which the sound can be heard. If the rotating disc short-circuited the receiver only a small part of the time and permitted the telephone current to reach the receiver during the greater part of the time, the disc would be set so that the sound in question could not be heard. Such a device becomes unsatisfactory when many other sounds are present because the opening and closing of the short-circuit causes a shock to the ear-phone diaphragm due to the abrupt switching on of the currents generated in the transmitter circuit, and the resulting impulsive effects on the ear make it very difficult to distinguish one sound from another.

The lower drawing shows a telephone receiver used as a transmitter in a similar circuit. The ordinary telephone transmitter and receiver are selective and cannot be used for quantitative measurements but will often be of service in determining the time of sharp sounds, if other equipment is not available.

ROCHELLE SALT-CRYSTAL VIBRATION DETECTOR

The so-called piezo-electric effect of the Rochelle salt-crystal permits a vibration detector to be made that is capable of use for picking up sharp sounds and which is not subject to effects from slower vibrations. These crystals can be grown to large size under proper conditions and very striking results can be obtained. If the crystal is twisted about certain axes, an electrical charge is set up at the center with respect to the ends, the current caused by these charges being great enough in the case of the larger crystals to cause audible sounds in telephone receivers. As we use them, the crystal is clamped longitudinally between two metal plates under spring pressure, an exploring rod being attached eccentrically to one plate so that any impulse imparted to it will apply a twisting force to the crystal. A strip of tinfoil about the center of the crystal acts as one terminal and the two end plates connected together serve as the other. A circuit diagram of a set-up used for making measurements of vibration intensity is shown in Fig. 14, the circuit including a timing switch by which the time of the noise with respect to the engine cycle can be determined easily providing the noise stands out from the other sounds. The impulse from the crystal is carried through an amplifying tube and transformer and is applied to a detector tube with a telephone in the plate circuit. A bias battery is provided which may be used as shown if only relatively coarse readings are required. The greater the disturbance to the crystal, the greater is the impulse applied to the final tube and the greater is the bias voltage, negative to grid, required to prevent this impulse from finally reaching the telephones.

The Rochelle salt-crystal has a rather high temperature-coefficient, and more or less variation in sensitivity will arise in the amplifier tube, so a means of adjusting calibration is necessary. This can be accomplished by attaching the crystal rod carrying the crystal and its mounting to a frame carrying a pendulum arranged to fall against the frame. The crystal is connected to the detector circuit as in Fig. 14. A weight on the small pendulum on the stand can be allowed to fall through a definite angle and deliver a definite blow to the metal upright strip to which the crystal rod is clamped. The detecting apparatus can be adjusted so that the sound can be stopped from reaching the phones at some predetermined bias voltage by an adjustable shunt across the primary of the transformer, which is not shown in the drawing. Calibration should be made as close to the time of reading as possible, preferably before and after a series of readings.

APPLICATION OF THE INSTRUMENT

Fig. 15 shows the apparatus, without the timing switch, in use. The instrument can be used to obtain readings of piston slap, detonation, bearing knocks, and other sharp or heavy sounds that stand out from the other noises. Readings can be duplicated easily by different observers. In using the instrument, the principle of its operation should not be forgotten.

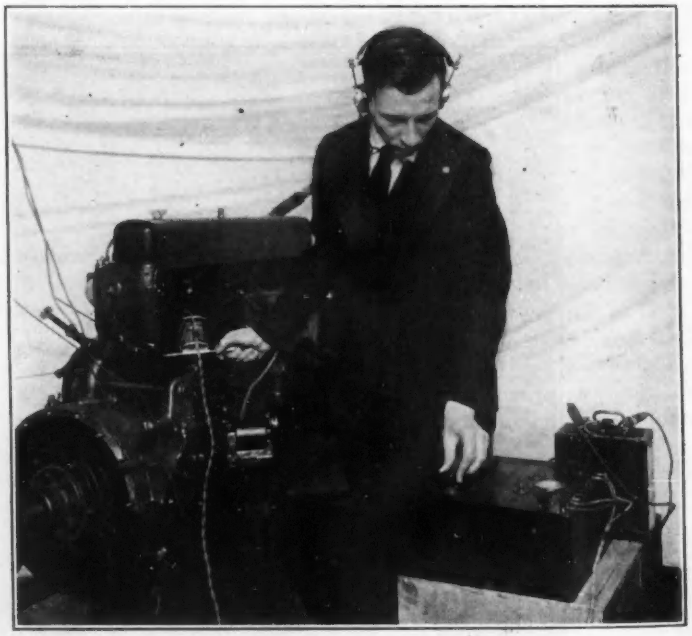

FIG. 15—SOUND DETECTOR APPARATUS IN USE

Measurement of Noise of Piston Slap, Detonation, Bearing Knocks and Other Sharp Sounds Is Made by Holding the Salt-Crystal Mounting Against the Engine at Various Places and Listening to the Sounds in the Telephone, at the Same Time Taking Readings from the Dial on the Instrument

(1) The readings taken depend on the vibration of some element in the mechanism, but this vibration does not necessarily have a linear relation to the sound in the air

(2) The crystal as used, both because of its own nature and because of its method of mounting, tends to pick up the high-frequency vibrations and give relatively greater results from them than from the lower-frequency vibrations. This is also true of the air as a transmitting agency, but the crystal is more selective than the air. This is a serious limitation in studying low-frequency noises

(3) The bias-voltage method of measurement gives a reading of the voltage required to stop the vibration of highest amplitude set up, even if this

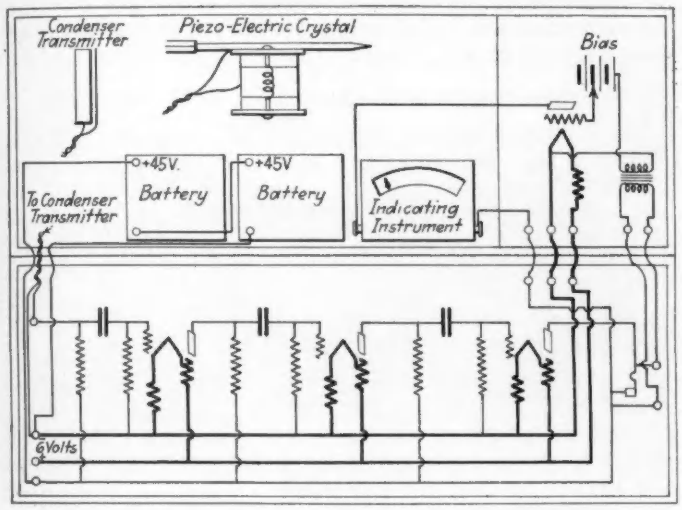

FIG. 16—CIRCUITS USED WITH DEVICE FOR MEASURING HUM AND HOWL

Pointer Readings on the Indicating Instrument Have a Definite Relation to Energy of the Air Vibrations. A Transformer Is Connected in the Plate Circuit of the Last Amplifier Tube, the Transformer Secondary Being Connected into the Plate Circuit of a Detector Tube in Series with a Low-Reading Ammeter. The Bias Voltage on the Detector-Tube Grid Is Adjusted to a Value That Will Bring the Plate Current to 0 on the Ammeter Dial. The Transformer Supplies a Rectified Alternating Current in the Microammeter and the Reading Increases Uniformly with Increase of Energy in the Sound-Waves Striking the Transmitter Diaphragm

is much greater than any other single vibration. Apparently the ear may receive a greater effect from several vibrations of a given amplitude than from a single vibration of a greater amplitude. This is well illustrated by the fact that if the instrument is applied to a gearbox, for example, and the bias voltage is increased slowly, the gear hum disappears long before the clicking and scratchy sounds caused presumably by the high spots on gear teeth that coincide only after intervals that are long as compared to ordinary gear-tooth meshing, or by variations in diameters of bearing balls or conditions of races. When one listens to the same gearbox, it is the hum that makes the greatest impression on the ear, and the clicking and scratching sounds can hardly be heard. In this particular case, part of the effect may be due to the selective action of the crystal itself

(4) The crystal and the circuits are very sensitive to electrostatic disturbances, hence care must be exercised to avoid taking readings on the ignition current or the conditions in the ignition circuit, rather than on vibrations causing some noise. The sound from the ignition is very characteristic, and errors are not likely to be made, particularly if one deliberately tries the instrument out by bringing the crystal close to the high-tension wiring. Careful shielding of crystal and wiring will eliminate trouble

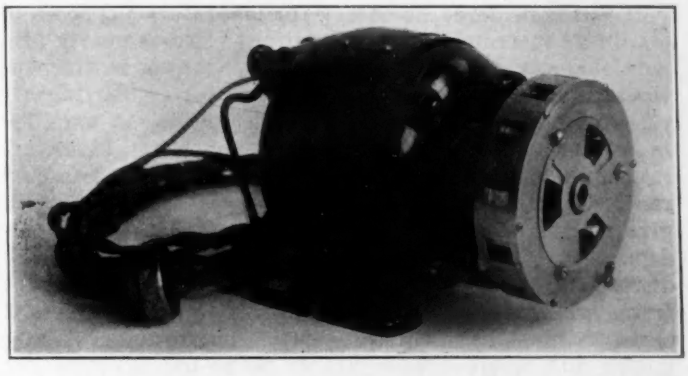

FIG. 17—SIREN FOR CALIBRATING SOUND-INTENSITY DETECTOR

This Can Be Adjusted To Produce a Standard Noise To Give a Definite Deflection on the Meter of the Detector When the Siren Is Set-Up at Some Definite Distance from the Transmitter. Calibration of the Detector Apparatus Is Accomplished by an Adjustable Shunt Across the Line at Some Convenient Point in the Amplifier Circuit

(5) The crystal is a rather fragile element in the equipment and has a high temperature-coefficient of sensitivity, hence it must be kept from extreme variations in temperature and humidity

In spite of these limitations, it is a very useful detector and is capable of many other applications than the one mentioned. If the crystals were more easily procured, much more general use would be made of them. The reader is referred to Appendix 2 for a partial bibliography on the use of the Rochelle salt crystal, which should be consulted before applying the crystal.

Thanks of the authors are due to the engineering department of the Western Electric Co., particularly to E. B. Craft, chief engineer, and to A. McLean Nicolson, who has been making and using the crystals for problems of sound transformations, first for permitting us to see their own work and, second, for supplying the crystals used in our investigations.

DEVICE THAT MEASURES SUSTAINED NOISES

Work with the combination of the crystal and the special circuits previously described had shown that this device was not adapted to a very necessary type of measurement, that is, the hum or howl, as the case may be, from gears or fans. Our readings had shown that the physiological effect of the sounds was due to their sustained uniformity and was not necessarily related directly to the maximum amplitude of any single vibration, as seemed to be the case with piston slaps and detonation. It was therefore decided to develop an instrument from which could be obtained a pointer reading having some definite relation to the energy in the air vibrations.

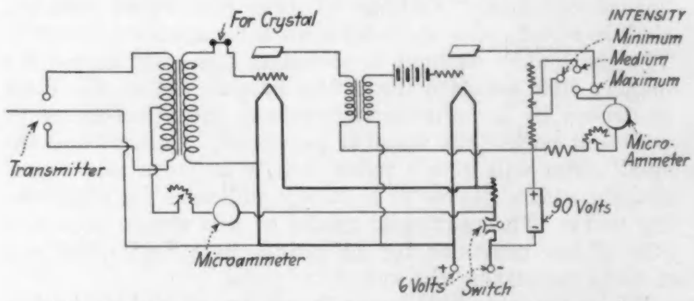

FIG. 18—CIRCUITS OF A SIMPLE SOUND-DETECTOR SET-UP

The Instrument Embraces a Stretched-Diaphragm Transmitter in Connection with a Transformer and Two Tubes Instead of Four, and Gives Promise of Being Useful for Work in Which Relatively High Accuracy Is Not Required

It was considered necessary for laboratory purposes to obtain an instrument whose readings were as nearly proportional as possible to this energy. Such an instrument would involve a transmitter or device for converting air vibrations into alternating electric currents, an amplifying system and a detector system, the latter being arranged so that readings proportional to the electric currents would be produced. If the whole system were to give readings proportional to the air vibrations and independent of the frequency, either each element must be distortionless or must give the same response to different frequencies involving the same energy, or else groups of elements must have this property. The ordinary transmitter and receiver were known to be too selective for our purposes. The Western Electric Co.'s engineering department has developed a condenser transmitter which is known to be practically uniform in its response to the total range of frequencies. The curve of sensitivity is very smooth and slopes always in the same direction. The effect of this slope can be compensated for by the design of the amplifier system, using a resistance-capacity coupling, as a result of which the electric impulses delivered by the system are made directly proportional to the air vibrations.

Considerable experimenting was carried out to determine the most suitable detecting device and finally a transformer was connected in the plate circuit of the last amplifier tube, the transformer secondary being connected into the plate circuit of a detector tube in series with a low-reading ammeter. A milliammeter or microammeter should be used that has a proper range with respect to the normal plate-current of the tube. The bias voltage on the detector-tube grid is adjusted to a value that will just bring the plate-current as indicated on the ammeter to zero. With these circuits the current in the microammeter consists of the rectified alternating current supplied by the transformer, and if the maximum current to be handled does not extend beyond the range of the straight-line characteristic of the tube, the readings on the microammeter will increase in a uniform manner with increase of energy in the sound waves striking the transmitter diaphragm.

Fig. 16 shows the circuits used with this device. Incidentally, one may comment on the fact that such a diagram is allowed to be a part of a paper presented to automotive engineers. A speaker presenting such a diagram before the advent of the wireless would have come in for severe criticism, but today many men will feel competent to set up such a circuit.

How the Instrument Is Calibrated

To calibrate the device, a standard-noise producer was made up consisting simply of a small rotor with radial blades inside a cylindrical shell, the latter having equally-spaced openings. Outside of this perforated rotating shell is a stationary cylinder with holes spaced uniformly. The stationary element is closed at the ends except for orifices that regulate the inflow of air. When the rotor is driven by an alternating-current induction-motor of sufficient power, the speed is practically constant and the small siren will give a noise that is uniform and reproducible with a degree of accuracy sufficient for engineering work. The particular model of this device shown in Fig. 17 has provision for adjusting the air admitted and thereby regulating the volume of noise.

When the standard noise is set up at a definite distance from the transmitter, the amplifier system can be adjusted to give a definite deflection on the meter, which reading serves as a base line to which all other readings can be referred. Calibration is best accomplished by an adjustable shunt across the line at some convenient point in the amplifier circuit. For the sake of reasonable constancy of calibration, the filament currents and the plate voltages on the tubes should be maintained at steady values corresponding to a stable condition of the tubes.

The outfit just described is, so far as we can learn, about the most accurate and is the most nearly universal in its application of any that can be assembled from elements already developed. More accurate methods of calibration are available than the one described.

Acknowledgment of assistance is made to the engineering department of the Western Electric Co., recently reorganized under the name Bell Telephone Laboratories, Inc., which supplied the tubes and amplifier elements used and the special transmitters that are absolutely essential to distortionless detection, and which gave valuable advice as to the application of this equipment.

Simpler Device for Measuring Air Vibrations

As it seemed desirable to try a simpler set-up involving fewer tubes, an apparatus has been assembled based on the use of the stretched-diaphragm transmitter developed by the Western Electric Co. for radio broadcasting, which, in connection with a transformer and two tubes instead of four, as in the first outfit, gives promise of being useful for considerable work in which the relatively high accuracy of the first outfit is not required. The circuits of this second outfit are shown in Fig. 18 and a convenient assembly of the equipment is reproduced in Fig. 19.

Such an outfit can be used conveniently for noise inspection of machines or elements of machines provided the proper precautions are taken. When using such an instrument for inspection, two important points must be remembered:

(1) The instrument, properly calibrated, measures a physical quality, that is, a disturbance of the air. When we have no reflection, the energy of this disturbance will vary inversely as the square of the distance from the source. It is thus vitally important that the position of the instrument, with respect to the sound being studied, be fixed accurately for each reading

(2) The relation between energy in a sound-wave and the effect on the ear for a definite frequency is a logarithmic quantity, that is, to double the effect on the ear, doubling the energy will not suffice; it will be necessary to increase the energy until its logarithm is doubled. This law, of course, would not hold true at the threshold value, or at the limit of tolerance. Hence, while good results can be obtained by setting a limit reading beyond which rejection is made because of noise, undue importance must not be assigned to fairly considerable reductions in the readings when the noise under consideration is considered too loud, as the effect on the ear of these reductions will not be likely to be sufficient to be satisfactory

The whole question of the relation between the energy in the air vibrations, which is a physical quantity, and the impression made upon the ear of an observer is entirely too complicated for extended discussion in the present paper. Telephone engineers, physicists and physiologists have given the question very extended study and the telephone engineers have adopted a system of units for measuring sound which is based on a logarithmic, rather than an arithmetical, scale. An incomplete bibliography on this subject is given in Appendix 3.

If the instruments described are to give readings that

have a definite relation to the effect upon the ear of the sounds measured, a logarithmic scale should be used. To apply it, an adjustable and calibrated shunt should be provided, by which the reading on the indicating instrument would be brought to the same value for each observation, the energy in the impressed sound being determined by the conductivity of the shunt. Such a calibration would be much more useful in attacking a problem of reducing a given noise to a tolerable degree. With the type of the instruments just discussed, cutting a reading in two on an arithmetical scale would mean a real reduction of noise but would also mean that many observers would be inclined to feel that no gain had been made, especially after the instruments had been taken away. Since an instrument with such a scale is unduly sensitive with respect to the physiological effect of a sound, it can easily be used for inspection or rejection of defective equipment, providing the standard is set properly. It must be conceded that there will be considerable

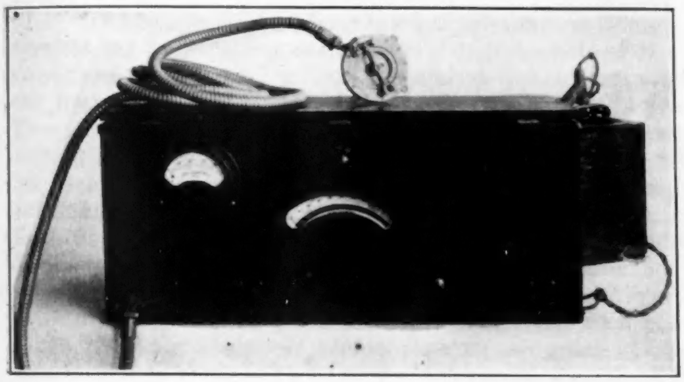

FIG. 19—ASSEMBLY OF THE SIMPLE SOUND-DETECTOR

chance of controversy with the manufacturing division in the border-line cases.

DECISION DIFFICULT AS TO PROPER METHOD

It is possible that there will be a great difference of opinion as to the best method to be followed in working on noise problems. Noises reach the ear through the air and for this reason it might seem to be more reasonable to make measurements of the air vibrations rather than of vibration of parts of the mechanism. It seems entirely reasonable that in the case of fan and gear hums, measurements of the air disturbance taken at positions corresponding to those of the driver's or the passenger's ear will be much more satisfactory in comparing cars of different design and structure than any measurements that could be taken on the mechanism itself. On the other hand, when working on a given design and comparing different units of the same construction, it seems altogether probable that satisfactory results can be obtained by using detecting instruments that really measure the vibration of the parts themselves rather than the vibrations impressed upon the air.

In locating the cause of a given noise, such measurements will, of necessity, have to be made. To do this, different types of devices for detecting the vibration can be used according to the quality of the noise under investigation. Thus, the crystal as used in the instrument first described can be connected with the amplifier system of the deflecting instrument, making the necessary minor changes at the point of connection. The crystal can thus be used to obtain readings that will have a definite relation to the vibrations of the parts. It must be remem-

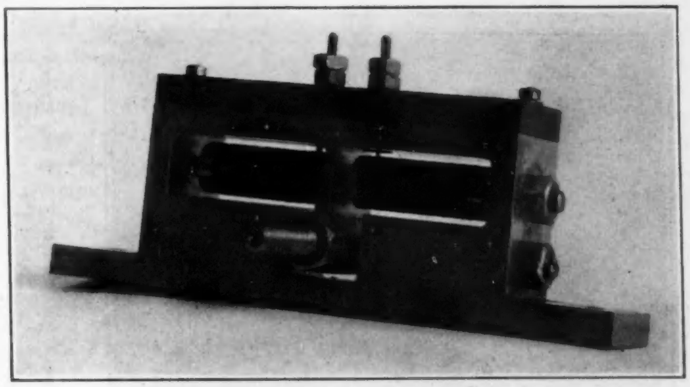

FIG. 20—TELEMETER FOR MEASURING FRAME STRAINS AND OTHER SMALL DISPLACEMENTS

Pressure Variations in the Two Carbon Piles Due to Movement of the Device in Relation to a Weight Suspended from the Tongue Between the Piles Are Recorded on an Oscillograph Element Connected in the Electric Circuit. The Device Can Be Used by Clamping It on the Frame or Engine Being Studied or May Simply Be Pressed Against the Member under Investigation

bered, however, that when so used the crystal, at least as we have applied it, has a selective action and may not give results that are at all satisfactory for low-frequency sounds. An ordinary watchcase receiver may have an exploring rod mounted on the diaphragm and if this rod is held against the part being studied, forced vibration of the diaphragm will result, the receiver acting as an electromagnetic transmitter. Precautions must be taken, however, on account of the possibility of selective action of the transmitter.

The two types of apparatus described were designed, first, with the idea of getting as accurate a piece of equipment for universal application as could be built up and, next, of seeing how useful a piece of equipment could be made by sacrificing to a small extent the accuracy of the outfit. Obviously, an ordinary microphone might be used in series with an amplifier system of the type employed in an ordinary homemade wireless receiver. It is undoubtedly possible to secure considerable useful information with such a piece of equipment when comparing different units of the same design so that any selectivity of the detector or the amplifier will not enter into the results. In this form the instrument might be used for inspection, if proper care were taken in obtaining and maintaining the calibration. In general, such an instrument would be likely to give very misleading results if a calibration which had proved satisfactory for inspecting one type of noise were used on another type, and the instrument itself, even with a new calibration,

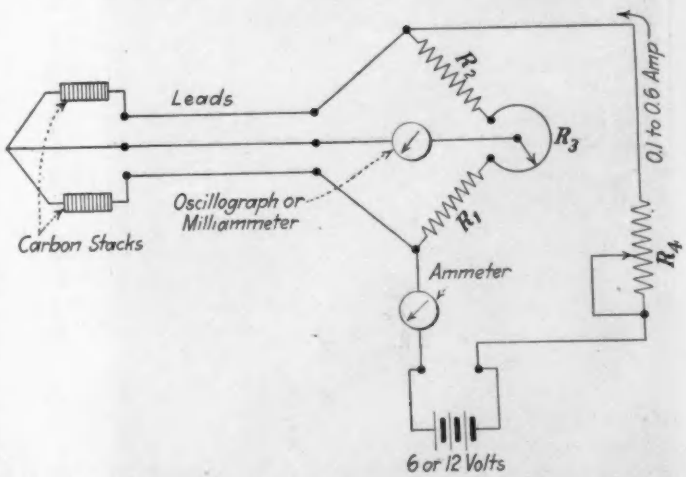

FIG. 21—CIRCUITS FOR TELEMETER AS SET-UP FOR TAKING READINGS

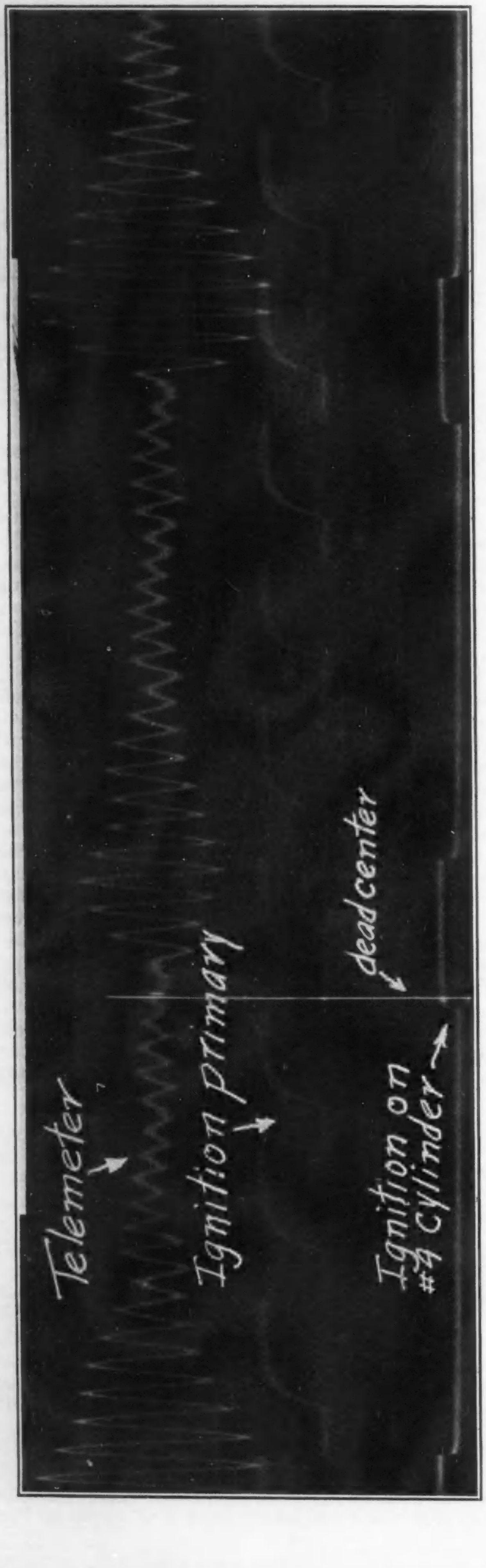

Fig. 22—Telemeter Record of Vibration Causing Low-Frequency Noise

The Vibration Was Too Low in Frequency for Efficient Detection by the Rochelle Salt Crystal. Actual Amplitude of the Vibration Can Be Measured by Providing Proper Damping

might prove unsatisfactory when applied to a type of sound to which it was relatively insensitive.

Most of the technical and scientific information required for the undertaking of work along the foregoing lines has been published in the scientific press. Appendix 3 gives an incomplete bibliography on this subject.

Use of Telemeter as Vibration Detector

The Bureau of Standards has developed an electrical-resistance type of telemeter that can be used in connection with the oscillograph for the measurement of small displacements. The device can then be used to measure the strains in frame members if so desired, and this is the principal use to which the instrument has been put.

The instrument itself is described in detail, together with many of its applications, by Burton McCollum and O. S. Peters.[4] A photograph of a preliminary model made for studying some of the possibilities of the device is reproduced in Fig. 20. The circuits, as set up for taking readings or records, are shown in Fig. 21, which is taken from the paper by the authors just mentioned.

It is obvious that if a weight is mounted on the tongue between the two carbon piles of the instrument, as shown, any accelerations applied to the whole mechanism will result in pressure variations on the carbon piles which will be recorded on an oscillograph element connected in the circuit. When thus arranged, the device can be used in a manner similar to the crystal, either by clamping the whole assembly on the engine or mechanism being studied or even by simply pressing the outfit against the member under investigation. We have found the instrument useful in this way for detecting low-frequency vibrations and locating the time at which they start.

Inasmuch as our instrument in the form shown is not damped, we cannot be certain of the duration or amplitude of the vibrations of the equipment which is acting on the telemeter. Fig. 22 shows a record taken of a vibration causing dull low-frequency noise, which vibration was too low in frequency for efficient detection by the crystal. It could be picked up by an electromagnetic transmitter but its audibility compared with the other sounds present was not great enough to permit accurate timing by the circuits of the lower drawing in Fig. 13. Accurate timing is obtained evidently by using a detector that tends to emphasize the particular sound being studied, which detector can supply enough current for an oscillograph element without the need of amplifiers.

Actual amplitude of the vibrations can be measured by providing the proper damping. If the outer part of the instrument is held rigidly, with respect to some element of a mechanism and another part connected to the tongue between the carbon stacks, the telemeter may be used to measure the amplitude of their relative vibrations. When so used, care must be taken that the maximum motion does not exceed the amount the carbon stacks can safely withstand. Modifications of the instrument, when properly damped, might be used as accelerometers. Proper design could easily provide a series of instruments for handling the entire range of car accelerations affecting riding-quality and the shocks applied to axles on the road.

Electrical Instruments Have Wide Application

The foregoing discussion has been limited to a few examples of the application of electrical instruments to measurements in the automotive laboratory. In some of these cases instruments working on purely mechanical

[4] See Technical Paper of the Bureau of Standards No. 247.

principles can make part or all of the mesaurements but in most cases the electrical instrument has rather definite advantages, either in case of application or in ability to determine times of disturbances, that justify its use. When an oscillograph is available, the applications mentioned and a long series of similar uses follow as a matter of course.

The uses of the vacuum tube and circuits built around it, for measurements of electrical quantities which had never previously been measured in the engineering laboratory, would supply material for a much longer paper. These have not been touched upon, although the application in our own case has been to elements of the ignition circuit which are applied directly to automotive purposes.

The automotive industry has developed with such striking rapidity because of the combination of an enormous market and of engineers and manufacturers sufficiently alive to appropriate and use everything that engineers in other lines had made available. In these days when the pressure for refinement has become so acute, we need to go behind the work of the engineers in other lines, back to the men who are attacking the elements of the problems in the physical and chemical laboratories. Every automotive research man should have a rather definite idea of the researches being carried on by the Bureau of Standards, by the more active scientists in our greater universities and by the large research organizations in other industries, so far as these industries can disclose their work in justice to themselves. From these sources it should be possible to obtain ideas that will lead to improvements and to great savings of time and expense in our own work, as compared with starting in from the beginning. This can be done successfully only if we are in a position to make some small return to the men and organizations in other lines who assist us. To be able to do this, we must get closer to the fundamentals of our own problems.

APPENDIX 1

The Oscillograph

A General Electric three-element oscillograph was used in making the torsional vibration records. Each element of the oscillograph is in reality a D'Arsonval galvanometer in which a small metallic ribbon forms both coil and suspensions. This ribbon passes down and back between the poles of a strong electromagnet. The current to be investigated is led through this ribbon and, since it passes through the two strips in the field in opposite directions, it will tend to bend them in opposite directions. A small mirror, bridged across the strips, will then show a deflection proportional to the current flowing.

With this metallic ribbon stretched tightly, these elements will have a natural period of about 5000 cycles per sec. By immersing them in oil, the damping can be made critical and so the mirror will follow any low-frequency current very faithfully. The motion of the mirror is recorded by throwing a strong beam of light on it, the reflected beam falling on a photographic film and producing the record. The motion of the beam gives the ordinate, which is proportional to the current, while the abscissa, which is time, is produced by the motion of the film.

The elements operate independently and the instrument used can draw three curves simultaneously. By the use of shunts or resistances, the oscillograph can be made to trace either currents or voltages. In the case of the torsional-vibration indicator records, one curve shows the torsional vibration and the other two are used for timing. This is done by the ignition primary current and a contact which shows when No. 1 cylinder fires.

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Gages, A Key Problem

By G. K. BURGESS[1]

THE system of interchangeable parts has been developed to a high degree by the automotive industry. This interchangeability is, in the last analysis, wholly dependent on the permanence and durability of the gages used.

Gages are "key" tools. This was strongly borne in upon the Ordnance Department of the Army during and after the late war. Coming out of the war with a large stock of gages for use in the production of munitions, the Ordnance Department realized that, if these gages did not hold their dimensions in storage, they would be useless should another emergency require their use. On consideration of the problem, it appeared that there was no assurance that these gages would hold their dimensions. Still more serious was the fact that present metallurgical knowledge could not produce gages that definitely could be relied upon in storage. The development of permanence in gages is thus an essential of any National preparedness program.

From the production point of view, durability in service, that is, high wear-resistance of a working gage, is of similar importance. Metallurgical knowledge on this point is again fragmentary. Many and varying opinions exist as to the factors governing the wear resistance of gages. The Ordnance Department wanted the facts and realized that the two problems of permanence and durability are as vital to industry, especially to the automotive industry, as they are to ordinance.

Instead of taking up the problem as an exclusive one of munitions or of ordnance, it was therefore attacked more broadly. The commercial problem has been given equal weight with the military problem, and all interested parties were given an opportunity to shape the program. The Ordnance Department, therefore, brought about the organization of a committee representing the War and Navy Departments, for the military angle; the manufacturers of gages, the users of gages, steel makers and the Bureau of Standards, for the commercial and the scientific angles. This committee first met in New York City, Jan. 10, 1922, and has identified itself as the Gage-Steel Committee.

The committee concluded that the problem, stated in its simplest terms, is two-fold:

(1) To find the steel or steels best suited to use in the production of gages
(2) To find the heat-treatment best suited to the steel selected

Of the many factors involved, the following can be regarded as of major importance:

(1) The steel selected must be a reasonably machinable one, capable of commercial production in a sufficient quantity for the purpose
(2) Its dimensional changes on hardening must be reproducible
(3) Its dimensional changes with time, after hardening, must be small
(4) Its resistance to wear must be high

The relative importance of the various factors depends to some extent upon the use to which the gage is to be put. For example, for a master gage, freedom from dimensional changes with time is of major importance; but, in the case of a working gage, which is quickly worn out, changes with time are of relatively little importance and high resistance to wear is of great importance.

The Committee soon appreciated that more could be gained by experiment than by discussion, and arranged with the Bureau of Standards to have a member of its staff put-in full time on the Committee's work. As the problems confronted were, to a large extent, metallurgical, the investigator was chosen accordingly and attached to the Metallurgical Division of the Bureau. Since the initiation of the experimental work, many basic data have been collected and distributed to committee members and other interested parties in the form of 12 progress reports.

The original problems chosen for study were permanence, dimensional changes on hardening and wear resistance. Laboratory work was started on each of these problems, but it soon developed that wear resistance was the most difficult and pressing of the three; so, attention was concentrated on it.

LABORATORY WEAR-TESTS

The purpose of the laboratory wear-tests was to provide a means by which comparative tests of the wearing qualities of the various steels and heat-treatments could be made without the delay and cost incident to making up actual gages and wearing them out in service. The laboratory work on wear resistance was started with the Amsler wear-testing machine, which produces a combination of rolling and rubbing action on the peripheral surface of disc specimens. The results with the Amsler machine showed an increase in wear resistance of tool steels with increase in drawing temperature, within the normal temperature-range of drawing for such steels. It also showed lower wear-resistance for Stellite than for tool steel, whereas Stellite has been found to be markedly superior in service.

Other attempts to reproduce service wear have been made also. One device consisted of tumbling cylindrical specimens in a ball-mill with an abrasive, and measuring the loss in weight of the specimens. Strangely, this distinctly different type of test gave results very similar to the Amsler test and, consequently, it is of little value under the conditions of experiment chosen as a criterion of gage wear in service.

It is well known that metals of high durability are difficult to lap. Following this lead, a lapping wear-test was developed with some success. This test easily distinguishes between a metal of very high and of moderate durability, such as Stellite and hardened carbon tool-steel. It is, however, not so positive when the differences in wear resistance are small as, for example, the difference between hardened carbon tool-steel and chrome-bearing steel. It is, unfortunately, limited at the present stage of development to testing three specimens at one time. Repeat runs generally will put the three specimens in the same order, but the total wear may be considerably different. This test has been useful in suggesting service-test experiments and in reducing the number of tests necessary to establish the effect of a given variable, but its final evaluation must be deferred until further service-test data are available for comparison.

SERVICE WEAR-TESTS

The difficulties of laboratory wear-testing showed that efforts to solve this subsidiary problem should be kept up, but that for immediate results actual service-tests are essential. Making service tests called for the active help of companies that could make them within a reasonable time, so an appeal was addressed to the automobile manufacturers and it met with fair response.

Dimensional specifications for plug gages were received from seven manufacturers. Only "go-gages" were tested, for they are obviously more suitable for test purposes than "no-go-gages." The gages were machined and lapped from steel furnished by the steel companies represented on the Committee, either by the Bureau or by the gage manufacturers represented on the Committee. They were hardened and measured at the Bureau. In all, 74 gages have been sent out and 24 gages returned for final measurement after having been worn below tolerance. Most of the 74 gages have been out more than 1 year. The results from the returned

[1] Director, Bureau of Standards, City of Washington.

gages, though superficial, are of interest to the industry.

The service wear-test data now available are given in Table 1. Two compositions of steel were used, as stated in Table 2.

The first series of tests undertook: (*a*) to compare carbon-tool steel *B* of Table 2 and chrome-bearing steel *M* of Table 2, (*b*) to show the effect of tempering temperature and (*c*) to compare water and oil-quenching. The B. S. Nos. 1 and 2 of each size are carbon-steel gages, and the B. S. Nos. 3 and 4 are chrome-steel gages. From Table 2 one can see that, in all three sizes, the carbon steel showed superior wear-resistance to the chrome steel. In the case of the two larger gages the difference is not very great, about 25 per cent; but, in the case of the smallest gage, it is pronounced. This is an observation of considerable importance, for there is a division of opinion among gage makers and users as to whether file-hardness is essential to high wear-resistance. The carbon tool-steel treated as indicated is normally file-hard, which the chrome steel is not. This crucial experiment requires further confirmation, and a study of the effect of quenching temperature will perhaps be necessary before definite conclusions on this point will be permissible.

The effect of tempering temperature is evident from a comparison of B. S. Nos. 3 and 4 with B. S. Nos. 5 and 6. The difference is rather small, considering the large difference in tempering temperature. The excessively high tempering-temperature of 300 deg. cent. (572 deg. fahr.) was chosen because the Amsler wear-test showed minimum wear for the same steels tempered at or near that temperature. As the service wear is definitely greater for the higher tempering, it appears that the Amsler machine does not give a reliable measure of gage wear.

The last comparison, that between water and oil-quenching, is represented by B. S. Nos. 3 and 4 and by B. S. Nos. 7 and 8. In both sizes there is no decisive difference between the water-quenched gages and the gages quenched in oil from a temperature 20 to 30 deg. cent. (36 to 54 deg. fahr.) higher. Tests on three other gages have been completed but, lacking confirmatory tests, they are not given.

While one can well hesitate to draw any specific conclusions from these limited data, it is nevertheless evident that reasonably consistent results can be obtained from the type of service test inaugurated and that it is possible to obtain valuable information from it. The orderly growth of such information is, however, seriously jeopardized by the small number of companies that have given prompt returns on the gages submitted to them. In fact, only two companies completed their test of eight gages within 1 year. In the case of two other companies, the Ford Motor Co. and the Chevrolet Motor Co., the gages have been prepared for either a part not in quantity production or for one which has been changed since the gages were submitted. The Cadillac Motor Car Co. and the Maxwell Motor Co., Inc., have gages under test at present, while a lot for a part which gives severe wear will soon be submitted to the Ford Motor Co.

While the Committee has been specializing on the wear problems, some other phases of gage-making have not been neglected. For example, difficulty was experienced with quenching cracks under certain hardening conditions. Such difficulties are a very great handicap when large-scale production is undertaken without skilled labor, and deserve special attention.

The committee membership is always open to those who are sufficiently interested to contribute as well as partake of the information being gathered. The technical data now available will be furnished gladly to interested parties who apply to the Bureau of Standards. The Committee would be pleased to receive from automotive manufacturers, or others, drawings of plan plug go-gages, of ½ to 1-in. diameter, the gage to be used on a regular production job of such a nature that it will be worn out in a relatively short time; a few days at the most, preferably a few hours.

If gage users will furnish the Committee with such gage drawings, it will gladly furnish a series of six or eight gages made to these drawings at no cost to the user, and with no obligation other than that an accurate record be kept of the number of pieces gaged and the conditions under which the gages are used, that the service wear-test be made and the results promptly reported to H. W. Bearce, secretary of the Committee, at the Bureau of Standards, City of Washington, and that the worn-out gages be returned.

TABLE 2—COMPOSITION OF STEEL USED IN OBTAINING WEAR-TEST DATA

Steel Symbol	*B*	*M*
Carbon, per cent	1.1	1.0
Manganese, per cent	0.3	0.2
Silicon, per cent	0.2	0.3
Chromium, per cent	0.0	1.4

TABLE 1—SERVICE WEAR-TEST DATA FOR GAGES

Bureau of Standards No.	Nominal Diameter, In.	Composition Symbol	Quenching Temperature Deg. Cent.	Quenching Temperature Deg. Fahr.	Quenching Medium	Tempering Temperature 1 Hr. Deg. Cent.	Tempering Temperature 1 Hr. Deg. Fahr.	Total Number of Holes Gaged	Wear at Entering End Total, In.	Wear at Entering End Holes per 0.0001 In. of Wear	Mean of Duplicate Gages	Remarks
1	0.7505[a]	*B*	800	1,472	Water	150	302	10,833	0.00030	3,610	3,870	......
2	0.7505	*B*	800	1,472	Water	150	302	12,809	0.00031	4,130		
3	0.7505	*M*	840	1,544	Oil	150	302	9,117	0.00034	2,680	2,860	......
4	0.7505	*M*	840	1,544	Oil	150	302	10,368	0.00034	3,050		
5	0.7505	*M*	850	1,562	Oil	300	572	8,791	0.00042	2,090	1,980	Badly Scratched
6	0.7505	*M*	850	1,562	Oil	300	572	7,428	0.00040	1,860		
7	0.7505	*M*	820	1,508	Water	150	302	9,442	0.00031	3,050	2,880	......
8	0.7505	*M*	820	1,508	Water	150	302	10,336	0.00038	2,720		
1	0.3753[b]	*B*	790	1,454	Water	150	302	2,493	0.00013	1,920	1,970	......
2	0.3753	*B*	790	1,454	Water	150	302	1,815	0.00009	2,020		
3	0.3753	*M*	840	1,544	Oil	150	302	1,515	0.00022	690	840	......
4	0.3753	*M*	840	1,544	Oil	150	302	1,565	0.00016	980		
5	0.3753	*M*	840	1,544	Oil	300	572	1,145	0.00016	720	770	Scratched
6	0.3753	*M*	840	1,544	Oil	300	572	1,225	0.00015	820		
7	0.3753	*M*	810	1,490	Water	150	302	1,295	0.00013	1,000	860	......
8	0.3753	*M*	810	1,490	Water	150	302	990	0.00014	710		
2	0.5615[c]	*B*	790	1,454	Water	150	302	6,000	0.00179	....	335	......
3	0.5615	*M*	840	1,544	Oil	150	302	6,000	0.00232	....	258	......

[a] Tested by Dodge Bros., Detroit.
[b] Tested by White Motor Co., Cleveland.
[c] Tested by Willys-Overland Co., Toledo.

Discussion of Papers at the 1924 Production Meeting

THE discussion of three of the papers presented at the Production Meeting held Oct. 22 to 24, 1924, at Detroit, is printed herewith. The authors were afforded opportunity to submit written replies to points made in the discussion of their papers. These, as received, have been included. As far as it was possible to do so, copies of the stenographic report were also submitted to the various discussors for correction prior to publication.

A brief abstract of each paper precedes the discussion for the convenience of those members who wish to refresh their minds as to the points covered without it being necessary for them to refer to the complete text. Those of the members who wish to look over the illustrations that appeared in connection with the papers as originally published, or to read the complete text of these papers, will find all of them printed in the November, 1924, issue of THE JOURNAL.

TOOL SALVAGE

BY L. A. CHURGAY[1]

ABSTRACT

RECLAIMING worn-out or rejected tools represents but a part of the work of a tool-salvage department. Many tools become obsolete due to engineering changes in the product and to changing the manufacturing methods. Surplus tools represent tied-up capital and to adapt these tools to changed shop requirements or dispose of them at a fair approximation of their original value requires careful planning.

All worn, broken and obsolete tools should be kept in separate containers; to throw them into a common scrap-box necessitates expensive resorting. Tool-crib attendants usually are directly supervised by the central-stores department.

Standard forms of purchase and inter-department requisitions are described and their usage specified. The men employed in this reclamation work are trained as specialists in operations such as welding high-speed steel tool-bits to carbon-steel shanks, and the like. They are classified as blacksmiths, heat-treaters, welders, machinists, tool makers, emery-wheel cutters, grinders and bench men. Details of tool-reclamation work follow.

As stated by the author, the salvage department is not organized to attempt to set a basis for an accurate percentage of new-tool expense saved by the use of reclaimed tools. Its ultimate purpose should be its functioning with the least possible friction and the rendering of the most effective service to all other departments.

THE DISCUSSION

H. W. ABBOTT[2]:—No doubt you buy drills; for example, a drill 41/64 in. in diameter in a special length to drill through a jig. You use 2 in. of the length and it is then too short for further use. Having no other hole of that diameter to drill in any other job in that or other shops, what do you do with that drill?

L. A. CHURGAY:—We regrind a large number of drills that have become obsolete to smaller sizes to suit other jobs and thus dispose of them. Drills that are too small in diameter to be so reduced in size are held for emergency calls or are disposed of through our by-product division. Do you refer to special sizes of drill?

MR. ABBOTT:—For example, consider a ¾-in. twist-drill. How many sizes can you reduce that drill, and what is your method for reducing it in diameter?

MR. CHURGAY:—We regrind that drill and reduce it 1/64 or 1/32 in. in diameter, as occasion may demand.

MR. ABBOTT:—Assuming that you do not have a requirement for a drill just 1/32 in. smaller than the discarded drill, how many thirty-seconds of an inch can you reduce that drill?

MR. CHURGAY:—We have not determined that by actual trial. Drills reduced to a smaller diameter for other jobs never come back; they are used up.

MR. ABBOTT:—Suppose you have a ¾-in. drill that is too short for its original job, but the length is only half used, and that you have no other ¾-in. holes to drill. Assuming that the next smaller size for which you have a requirement calls for a drill 11/16 in. in diameter and you cannot reduce it to that size, what do you do with the remaining length of that drill?

MR. CHURGAY:—We regrind the ¾-in. drill to 11/16 in. diameter, or dispose of it to one of the numerous salvage men. We also correspond with many out-of-town firms and exchange lists of tools that have become obsolete; by consistently following this policy, we find we dispose of a considerable quantity of such tools. On the other hand, as the other firms also seem to have a supply of tools, we buy from them to meet a portion of our production requirements.

MR. ABBOTT:—Our company works very closely with your company on the exchange of obsolete sizes of new drills and other small tools, but what do you do with the ¾-in. used-drill that is too short for use? I have yet to find anybody who will buy one.

MR. CHURGAY:—All our purchase requisitions for tools are forwarded to the salvage department, thus keeping it in constant touch with all the current tool-requirements of all our plants.

A MEMBER:—You spoke of the use of the welding machine. Can you not saw off the shank and put on a longer shank? I have seen factories in which that is done.

MR. ABBOTT:—You mean, I presume, to put an extension piece in the middle between the twist and the shank?

A MEMBER:—That was done to a great extent during the war. So long as the shank is sufficiently stable and the high-speed-steel piece is about 2 or 3 in. long, you can do that without much trouble. In some factories where a good hard guide is wanted for drill bushings, they put a hardened sleeve right on top and guide from

[1] Engineer, production division, Maxwell Motors Corporation, Detroit.
[2] Advisory staff, General Motors Corporation, Detroit.

the sleeve, the drill doing the work down below, as in counterboring.

CHAIRMAN K. L. HERRMANN[3]:—For most front axles having the section where the steering-knuckle fits in, a long drill is required for drilling the hole. Those drills usually are only 2 in. longer than their minimum size and they do not last very long. The drill costs $14 or $15, perhaps less at this time, but its life is too short. Is there any one here who actually salvages such drills in any definite way?

A MEMBER:—We had, at the Chandler plant, a serious proposition on drills. During the war the company built tractors and when I went there, about 3 years ago, it had accumulated about 1 ton of twist-drills. No market in Cleveland could be found for them so we made extension shanks, turned the taper shank down and made an extension collar and used some of them up in that way. We tried to dispose of the rest through shops but were unable to do so. Finally, we were obliged to sell the drills as scrap at 25 cents per lb. to the high-speed-steel people, who were willing to take them in trade at that price. The account was held open and the Chandler company took its pay in tools and other high-speed steel that it could use.

A. A. KUENY[4]:—We have not found such salvage very successful, except with very large drills. We have always found a place to use up the smaller size drills on some other job. In case of three-lip or four-lip drills, we have tried cutting off and setting them out. We have sent our welding work out, but that is rather expensive; if we had a welding machine in this department, we might do it successfully in our own plant.

MR. ABBOTT:—If this ¾-in. twist-drill has to be scrapped, assuming that the shank end is carbon steel and the twist is high-speed steel, what is the practice in your salvage department for getting rid of that drill if it is of welded-shank type as made by the drill manufacturer?

MR. CHURGAY:—When, in the opinion of the salvage department the drill is in such condition that it cannot be made use of, then it is scrapped and is sold as scrap steel.

MR. ABBOTT:—Do you separate the carbon shank from the high-speed steel part of the tool?

MR. CHURGAY:—Yes, if the high-speed-steel part of the drill justifies salvaging.

MR. ABBOTT:—What is your process for separating the high-speed-steel piece from the carbon shank?

MR. CHURGAY:—The method of separating is left to the salvage department's judgment. If the drills are to be sold as scrap, the drills are broken at the shank; if the drills are to be salvaged, the shank is cut off with an Aloxite wheel.

L. P. FREEMAN:—What is the general attitude in the different departments toward a salvaged tool? When a foreman gets one and knows it as a reclaimed tool, what is his attitude?

MR. CHURGAY:—The foreman does not know that it is a reclaimed tool, as the salvage department does not furnish tools directly to the various departments. The tool that is salvaged goes from salvage to the central stores, where it is accepted as a new tool and handled as such. These tools are sent from the central stores to the various tool cribs throughout the shop, and the men draw them on replacement requisitions as new tools.

MR. FREEMAN:—You think there is no difference between a salvaged tool and a new tool?

MR. CHURGAY:—No; if the salvage department felt that it could not salvage the tool properly so as to make it serve and look like a new tool, salvaging would be discontinued. It would make a poor impression on the shopmen if they knew that they were working with salvaged tools.

MR. ABBOTT:—I have seen that rather successfully worked out in one of the divisions of the General Motors Corporation. Their method is to have any department buy a drill or any other tool by requisition from stores when they originally put it to work. The value of that tool is written off then and there. When that tool eventually goes into salvage, it is offered gratis by the salvage department to any other foreman in the entire plant that will use it. The department tool-supervisors keep in close contact with the salvage department. They take the tools, gratis, from the salvage department to the toolroom for any conditioning necessary for the new use to which they will be put. The tool supervisor, assuming ownership of the gratis tools, pays the toolroom for the necessary work, which is much less than he would have had to pay for new tools. The salvage department salvages no tools.

The department foremen in that shop are judged by a budget, bonus or merit system which has caused them to have great pride in the reduction of overhead expense. It is soft picking for them to get discarded tools for nothing. I know that every one of them is endeavoring to get his tool cost down, and the salvage department is practically always clean of tools. In fact, there is one foreman operating a small department that buys practically no tools. He "hounds" the shop and picks up discarded tools to run his department free of tool expense. He has certain jobs lined-up from which he gets discards en route to the salvage department. The splendid results in this shop are worthy of consideration by every other shop.

E. A. HOENER[5]:—We have tried a similar system of salvaging tools, trying to get the foremen to use them. On some occasions, in conducting tests on new steels for tools, we have developed a new steel tool that perhaps doubles or triples the production on a particular operation. When we tried to salvage some of the tools that were made of the previous kind of steel we had, the men noticed the difference. I do not altogether see how you get your men and foremen to accept salvaged tools without knowing them as salvaged tools. It may be that the tools can be so well dressed up and polished that the factory foremen do not know that they are salvaged tools, but we have never been able to accomplish it.

In connection with drills, we have a considerable amount of countersinking to do and we use in that way a great many of the short drills that are broken off, which helps us to salvage many tools.

MR. KUENY:—We have that same trouble, to a certain extent, with regard to having the foremen use salvaged tools. Some foremen will use all the salvage they can, and others almost need to be forced. However, that could be overcome if the system of "allotments" were carried out. We make allotments of tools for every job in each department throughout the plant. Statistics are compiled three times monthly that show the cost for new tools. As a result, the foreman who wants to be kept on the job is one who will use up all the salvage he possibly can. No doubt exists that management can compel a foreman to use salvage in that way, so long as the salvage is handled in the proper way.

[3] M.S.A.E.—Assistant manager of methods and standards division Studebaker Corporation of America, Detroit.

[4] Studebaker Corporation of America, Detroit.

[5] Firestone Steel Products Co., Akron, Ohio.

Mistakes can be made in handling salvage, perhaps keeping a foreman from using it because some scrap tools are reclaimed and not enough care is taken in inspecting them for hardness. Often, the tool is partly worn-out or dull because it is soft and the salvage man, if he does not test the tool for hardness, may have it ground and send it out on another job. Naturally, the department foreman that receives such tools has trouble in setting them over again, as with milling cutters and shell reamers, and it causes him extra work; but, if proper care is taken in inspecting the tools for hardness and they are sharpened again, no reason exists why a foreman will not use the tools and be glad to get more.

CHAIRMAN HERRMANN:—To add to what Mr. Kueny has said, when a department foreman's allotment is say $5,000 per year for a certain number of cars and he runs over the allotment say $3,000, he sees from his monthly report that he has cost the company $3,000 more than he should. That is probably equal to his salary and so he soon improves. The competition is rather keen among the foremen in our plant to stay below their allotments. Many of them stay below 60 and 70 per cent under the allotment, which is governed somewhat by the amount of salvaged tools a man can use. The competition among the foremen as to what their percentage will be in efficiency of perishable tools is determined in that way. Our plant superintendents keep a chart in their offices showing each individual's standing at all times so that, whenever a foreman goes to that office, and that is three times a month, he sees where he stands.

A MEMBER:—Mr. Freeman said that some foremen complain about using those tools, and then I hear that some foremen are hounding the shop trying to find salvaged tools. Mr. Churgay presented the fact that every tool has a gear mark or color. There should be little difference between the brand new tool and the salvaged tool. At the Ford plant they give each man a little box of tools; he does not run back and forth, but turns the whole box in when he goes home in the evening. The upkeep is less and the breakage is less. If a man is hand-drilling and notices that the drill is somewhat dull, he puts in another one. There is little friction, if you place enough tools in circulation and have the inspector pass upon them.

CHAIRMAN HERRMANN:—How are tools allotted to the different departments?

MR. ABBOTT:—The scheme that I have seen is based on the performance of the previous 6 months and each foreman is allotted a certain amount of tool value per unit built. Often, bonuses are set on reduction of expenses; at least, the foreman is checked-up on the amount of money he is spending for tools and maintenance in his department. I have seen considerable pride induced in some factories by trying to hold first position in the reduction of expenses per month. If the management is keen enough to budget each department, and the foremen really have an interest in the plant as a whole rather than in their own department, the tool-salvage problem can be whipped. If they get to it, tool costs will be greatly reduced.

POSSIBLE ECONOMIES IN AUTOMOTIVE MACHINE-SHOP OPERATIONS

BY A. L. DE LEEUW[6]

ABSTRACT

THIS paper is confined to a discussion of machine-shop operations, and is intended to indicate by a few examples certain important economies that might be introduced in the shops of the automotive industry. It deals chiefly with the economies that can be effected without much capital outlay, though others are also mentioned. Calling attention particularly to the fact that, in the past, improvements of methods and of equipment have been confined largely to the more important operations on the more important parts, and that relatively little study has been made of the smaller pieces and the less important operations, emphasis is placed on the necessity for carefully determining which tools and which makes of tool will best serve the purposes for which they are intended, and for carefully sharpening the tools and providing means of setting them accurately. The various auxiliaries are discussed and, in order to confine the paper as much as possible to actual cases, one definite operation, namely, drilling, has been chosen as the chief example.

THE DISCUSSION

CHAIRMAN JOHN YOUNGER[7]:—Mr. De Leeuw's paper is suggestive of many ideas. One is the matter of factors of safety for drills and other small tools; what they should be and whether we should abolish them. Another, is whether to run drills to the limit or to have a factor of safety that will bring about predetermined life periods for small tools.

DR. GEORG SCHLESINGER[8]:—To know whether a twist-drill is all right, one must be able to measure it. The measuring must begin on the cutting edge. It would be difficult to test all the drills of an automotive shop and, even if that were done, the result would depend upon the skill of the operator. I think it is simpler to investigate the twist-drill grinding-machine, by which I mean to check the grinding machine every morning so that the lips of the twist-drill will be symmetrically and correctly ground.

A small machine had been developed that affords a means to check-up the twist-drill for accuracy of the relief and for correctness of shape of the point. The operator depends wholly upon the machine. He puts a twist-drill in the center of the chuck, which is coincident with the chuck of the grinding machine. The machine measures on 4, 5 or 10 circles to the relief angle and this is recorded on a diagram on the drum as shown in Fig. 1. If the twist-drill is turned around about 180 deg., the other side is brought exactly to the same origin and one can see at a glance if the twist-drill is symmetrical and whether the relief is correct or not. About 5 min. is required to make the record.

The vertical drilling-machine is today one of the most used machines in every shop. It is a very simple machine. Everybody feels able to design it and everybody criticises it. When such a machine tool is to be bought, one ought to be able to buy it according to specification, just as a steam-engine is specified by its consumption of steam and by the actual horsepower that has been demanded. One ought not to criticise the interior elements of a vertical drilling-machine unless he is a designer.

[6] Consulting engineer, New York City.
[7] M.S.A.E.—Editor and publisher, *Automotive Abstracts*, Cleveland.
[8] Professor of engineering, Charlottenburg Technische Hochschule, Berlin, Germany.

If one can test the machine as it is, simply by replacing the regular table by the gaging or testing table, putting the correctly ground drill into the machine and determining whether, within a certain time, it produces the desired number of holes while using the minimum of power, this affords means for ascertaining that the drilling machine is all right. A machine for accomplishing this result has been developed also.

One question is: "What is the minimum of power?" Generally, nobody cares whether a vertical drilling-machine uses 5 or 6 hp.; but, if you multiply that difference by 1000 or 2000, or the number of holes bored by the twist-drills in 1 hr., the total difference is 2000 hp-hr. and this rises to such a great amount in production that it pays to see that drilling machines are in order.

The machine for testing vertical drilling-machines is made in several sizes; one of which is capable of testing a big vertical drilling-machine of 45 hp. that is able to use a drill of 3-in. diameter at high speed, say about 60 or 80 ft. per min. circumferential speed and acting up to a 0.1-in. feed, which produces a chip that looks like a big roughing chip from a lathe. That may be the highest stress. For tests at 0.01 or 0.02-in. speed, you cannot use such a big testing-machine, but must use another smaller one.

Three attachments make it possible to cover all the drills in a shop, proving whether the drilling machines are right and whether the drills are ground correctly. On big machines such measurement is not easily made because two things are to be measured, the turning movement, or torque, that gives the cutting ability and the feeding power that gives the crushing action to the axis of the drill. They can be determined very easily, separately, by the gages because in the vertical drilling-machine the driving-gears are separate, one for feeding and one for driving the drill, and the two gearboxes to do this work can be supervised to see if they are in order or not.

Some will say that such testing is a thing for scientific investigation; it is not practical. All these things are always developed in the Charlottenburg University of Berlin, Germany, and they are in use in industry there. We had to work with the twist-drill manufacturers. They said, "If your attachment is all right, you must be able to decide if our twist-drills are correctly designed."

A twist-drill looks simple, but it is a tricky tool. You can change the lead, the angle of relief and many other details; in fact, you can change the entire design. We worked with the biggest German firms that made twist-drills in all the different shapes we wanted to have.

Mr. De Leeuw said that you can pick out two good firms and one will deliver a twist-drill that will run 600 holes and the other one will deliver a twist-drill that is good for 2 holes only. If that is true, then I believe something is wrong. The twist-drill may be wrongly hardened or something else may be wrong which should be changed, because such differences show that some manufacturers are out of competition altogether.

The first thing for us to find out is whether the drills are correctly hardened and, if they are not, we must reharden them to give fair competition. Then we must have the same material and apparatus, as I explained before. We measured the torque and the thrust and compared the different angles ground on the ordinary twist-drill grinding-machine that you may buy on the market as standard.

It is also of the greatest importance to accommodate the grinding of the drill to the material to be bored if it is of nickel steel, tool steel, wrought iron, brass or cast iron, because of the relief of the cutting edge, and the angle of lead must be changed in the twist-drill, the same as in a turning tool. If you do not follow such practice, you may have a great loss without knowing it. The flat drill that a good many people use for chrome-nickel steel is, in this case, very effective. For wrought iron it takes 13 per cent less torque and 14 per cent less thrust, which is considerable. That flat fluted drill which is often recommended today for drilling sheet iron, and especially brass, in wrought iron takes 2.8 per cent more power for turning than for crushing, and it is obsolete altogether; it should not be used. The consequence is that you must pick out the correct grinding for the different purposes in your shop and must consider the pieces to be drilled. For instance, if they are too elastic, you must provide for that. Iron builders cannot use twist-drills of the ordinary hardness; they must be a little bit softer. The apparatus I have mentioned makes it possible to find the right material for the right tool.

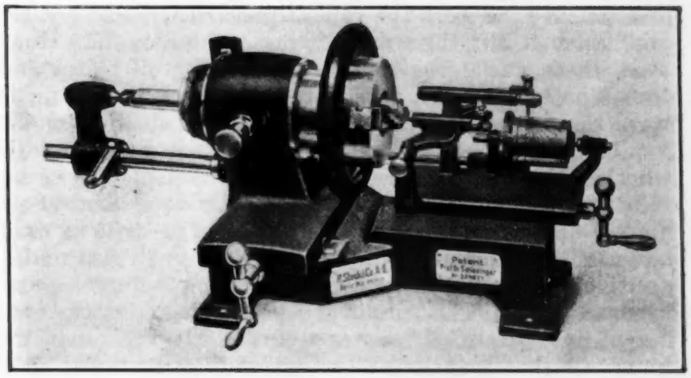

Fig. 1—Machine for Testing Drills
The Machine Affords a Means of Checking Drills for Accuracy of the Relief and for Correctness of Shape of the Point. The Operator Depends Wholly upon the Machine. He Puts a Drill in the Center of the Chuck, Which Is Coincident with the Chuck of the Grinding Machine, and the Measurements Are Recorded as a Diagram on the Drum. When the Drill Is Turned through an Angle of 180 Deg., Its Opposite Side Is Brought Exactly to the Same Point of Origin, Making It Immediately Evident Whether the Drill Is Symmetrical and Whether the Relief Angle Is Correct. The Entire Test Occupies about 5 Min. A Somewhat Similar Machine Also Is Available for Testing Vertical Drilling-Machines, and the Drills Used Therein

Eugene Bouton[9]:—Mr. De Leeuw emphasizes the importance of having drills machine-ground to the correct angle and clearance at the point. It has been my experience that this is very good practice to start a job off but, in many cases, a modification of the cutting angle and the thinning-up of the point will give more production than if the drill is ground correctly. An example of this would be in drilling brass, and also for automatic-screw-machine work. A drill ground with the correct angle will have a tendency to force the bar through the collet chuck; whereas, if the angle is modified and the point thinned, the thrust on the bar is lessened and a greater hourly production can be obtained.

With reference to the efficiency of pneumatic tools and to air-chucks in particular, it seems to me that the references you have made are not applicable to a modern automobile plant because such variations in the normal pressure of the line would not be permissible. In some cases, however, the normal pressure does vary, but it is a common practice to order tools to operate at about 10 lb. less than the normal pressure. In such cases, it is necessary to install a reducing valve or compensating

[9] M.S.A.E.—Supervisor of time study, Chandler Motor Car Co., Cleveland.

valve to maintain the pressure at the tool whenever the pressure in the line is increased. The normal pressure could then vary 10 lb. upward or downward, and be compensated for by the valve to the air-tool without interfering with its operating efficiency.

Why was a weight used to force the drill through the test piece instead of using a fixed feed per revolution? Your method would not have a tendency to determine the torsional strength of the drill, and would not test its penetrating qualities. Would your method give better information than a test similar to one in which the drill would be used in actual machining conditions?

A. L. DE LEEUW:—Answering the question with regard to the weight, I set out with a definite purpose; that was, to determine the time required to dull the drill to a 50 per cent longer time of penetration. If we had a positive feed, positive as to a certain number of inches per minute, then all drills at all times would go through in the same time. I had to find some way by which I could vary the time, and, to do so, had to keep something constant. The thing I kept constant was the pressure on the drill. I realize, of course, that the rate of penetration was not always the same; when the point of the drill first touched the work the rate of penetration was greater and, when it left the work, it was greater again. However, these variations were the same for all plates and for all holes. In other words, the conditions for all drills were the same. We were then able to find at least the number of holes to be drilled, although if I were asked whether the number of holes to be drilled would be an indication of anything else, I would say: "No, it is merely an indication of the ability of the drill to drill holes." The number of holes it might have drilled under positive feed might have been something different from what we found. The "proof of the pudding is in the eating of it." Here, it was applying the things that we found by that test to the actual shop operations. We did find that we got an enormous increase in drilling production by substituting the better drills for the poorer ones.

As to the air pressure, if we had a reduction of from 80 to 70 lb. per sq. in. only, it would not be bad. However, in one of the departments where air-chucks were in use before we took hold of it, we found that the pressure sometimes would go down to 40 lb. per sq. in. or less, because the compressor was too far from the point where the air pressure was applied, water in the pipes collected, and there were leakages which reduced the pressure far below the point at which it was safe to operate the chuck. That was easily overcome when a small compressor was put into the department.

G. E. MERRYWEATHER[10]:—One of the big drawbacks we found at the Locomobile Company years ago was the cost of the air. The trouble with air is that you have leakages. We intended to put in a new compressor, but the engineer got the "fresh-air" joints tightened up by putting some ammonia into the intake. If he got a whiff of that, it served as a notice to tighten the joints.

CHAIRMAN YOUNGER:—Will Mr. De Leeuw tell us the reason for the tremendous discrepancy between the records for drilling and the actual drilling feeds and speeds? If you take another analogy, for example, if there are not speed officers about, you can run up to 45 or even 60 m.p.h. in your automobile, which represents roughly about 50 per cent of the total speed that your machine is capable of; a train will run about 50 to 60 per cent of its maximum speed, but if you take a drill such as was used at the recent tests at Atlantic City, with a very rapid penetration, the large number of cubic inches of stock removed and all that, then consider the actual drilling conditions in a shop, tremendous discrepancy will be found. Is there any explanation for that, other than pure ignorance?

MR. DE LEEUW:—Of course, it is never entirely safe to try to duplicate test conditions in the shop except when you make your own test. It is true that the average rate of feed and speed of a drill is far below what it could be, and the reason is exactly the same as why speeds for turning, milling and planing and all kinds of speeds and feeds are less in most shops than they could be. The reason lies in that the individual operator has at present too much to say as to what speed and feed he shall use. I do not accuse the operator at all of deliberately reducing the feed or speed, but this is what the man does. He gets a number of pieces and finds that he can run, let us say, at 70 ft. per min., then he gets a few pieces on which he breaks a drill or spoils a milling cutter or ruins some other valuable tool and the foreman or somebody else finds fault with him for ruining the tool, so he reduces the feed or speed, brings it down, we will say, to 60 ft. per min. and, thereafter, runs that job at 60 ft. per min. If, a month later, he gets another piece on which he again ruins a tool because the piece is unusually hard, he reduces the speed to 50 ft. per min. and, having been criticized twice, he makes doubly sure and reduces it to 40 ft. per min., which he sets as his standard speed and it will remain his standard speed and feed until he finds a still harder piece. In other words, the worst piece he ever found is the standard by which he governs his production. That is the main reason why all feeds and speeds, with a few exceptions, are less than they should be.

In regard to what Dr. Schlesinger said about the determination of the amount of power required. The saving in actual power when you multiply the saving on one machine by perhaps 2000 or 3000 machines, that is important, so far as the cost of power is concerned but, as a whole, the cost of power in the machine-shop is small compared with other items, and it would be rather hard to awaken interest in saving a small number of horsepower a year. On the other hand, each horsepower you use more than is necessary is 1 hp. used exclusively for the ruination of the tool and the machine, for it does nothing else. If it requires 1 hp. to run the drill, whereas it might be run with ½ hp., the extra ½ hp. will not do very much harm to a machine that is rugged enough to stand another ½ hp. but it certainly will ruin the drill and make you believe that your feed and speed are too high, and you will reduce the standard just as the man at the drill-press did.

MR. BOUTON:—How can the operator reduce the speed and feed on his machine, when piecework governs the production somewhat? Is it not a fact that the foreman of the department, or of the rate-setting department in a shop where they have one, regulates the speed and feed rather than the operator? Machines in practically all automotive plants have a capacity for fixed production and the management expects to get that production every day. Certainly, the operator should not be allowed to reduce the speed and feed below that at which the hourly production is set, on his own initiative and without proper supervision.

MR. DE LEEUW:—The thought I had in mind is not that the operator reduces the feed or speed after it has been set for him, but that the feed and speed have been reduced before they were set. We are drawing on past

[10] M.S.A.E.—President, Motch & Merryweather Machine Co., Cleveland.

experiences when we set the feeds and speeds, when we set the time on a piece, except in a few isolated cases, and the previous speaker may refer to such cases in which an actual scientific test is made as to the possibilities of the machine and the drill to get the greatest production, which is merely another way of saying to get the least cost per hole. There, of course, what I said does not apply but, as a whole, so far as I have been able to observe, I would say that 9 times out of 10 or possibly 99 out of 100, the time set is based on actual experience in the shop. That time is set perhaps by the planning department, which, as a rule, gets its information from and is largely influenced by the foreman, and the foreman gets his information from actual occurrences.

Let us drop the drill for a moment. When a man damages a milling cutter that costs $60 and damages it badly, the foreman says, "Well, yes, that speed is too high," and he does not feel as if he wants to take another chance on a similar performance, because the foreman also gets blamed occasionally. If he shows an excessive breakage of tools, it is rather natural to think that he is doing something wrong, so he does not take the chance, he does not have authority to do it. Therefore, the foreman is controlled largely by actual occurrences, the breakages of tools and machines and the stoppage for this, that or the other thing, he is held responsible for whatever happens when a machine or a tool breaks. It has happened not only on a single day before the time was set but it has been happening for years and years. The man has gradually acquired his experience through years in the shop, perhaps 10 or 20 years, and from contact with men who have had similar experiences, and there you are.

The only way to get above and beyond this point is through actual testing of possibilities to find an average. For instance, if we find that a tool breaks occasionally on a certain piece, somebody should collect data to determine what percentage of the total operations this may be. If it happens once in 1000 times, that may not be important, but if it happens once in 100 times it may be serious enough to warrant reduction of the feed or speed. It is along these lines that tests should be made.

MR. MERRYWEATHER:—Dr. Schlesinger made a remark that I think we might consider. He said that the tests were made at the Charlottenburg University. I think they have a plan in Germany of cooperation between the universities and the State and the industries, a contact we do not have in this Country but which is a wonderful advantage. For instance, if a manufacturer there, as I understand it, has some drills he wants tested he does not go to some locked room where they have a special machine for running tests, but the work is carried on by the university and the test is official. A certain cooperation exists between industry and the university that is wonderfully beneficial to both sides.

As I understand it, if someone here wanted to get an official test made on a certain drill to be operated, they could send it to the Bureau of Standards where the tests would be uniform and along some specific line which would indicate an exact difference in the quality of the articles tested, as they do in Germany, instead of being carried on in different laboratories under different conditions.

DR. SCHLESINGER:—One of the very few good consequences of the war is the working together of industry and science. Germany had to develop many things, such as a substitute for leather because it had no leather, a substitute for good American and Russian oil. You know what it means when you have a bad oil in the machine-shop; if you are not aware of it and the machine-shop stands still from Saturday noon until Monday morning, no machine can be run because the oil is sticky.

We had to do the same thing with machine-tool bearings. We had no brass and no copper, so we had to substitute another bearing metal and to find new limits between lineshafts and bearings. The cutting edges of the tools were a very important matter and, because we had no tungsten, we had to replace tungsten by molybdenum and similar chemical elements. One manufacturer sent us a belt made of paper and we tested it for him and sent him a note in a couple of days saying, "This is a failure, you must change it in this way or that." He made the change and a week later he sent us another product; we tried it again until, by cooperation, we got a useful result.

From 1897 to 1904 I was with the Ludwig Loewe Co., Berlin; for 7½ years, from designer to being assistant to the general manager, so I know something about tools and about machine tools. When I went from actual practice to the chair of Charlottenburg, I founded its laboratory. That laboratory grew from small beginnings created by the government in 1905 and 1906; the means furnished by the government were very small. Today it is a great and well-known institute, very much used by the whole machine-tool industry. But the investigations, paid for by the manufacturer, must generally be kept secret and we are seldom allowed to publish the results.

In some cases our investigations led to applications for patents and from these sources we could improve more and more the installation of this laboratory and its personnel, which must be composed of highly skilled individuals who can do the difficult measuring which is often necessary.

The twist-drill testing-machine is not the only instrument I could show you. We have learned to obtain the balance of a lathe, and have developed another lathe tool that is much more effective than the best type of tool on the American market. I investigated the lineshaft, its ball and roller bearings, the best oil and the like; further, the electric drive for machine-tools, together with the necessary standardization of the arbor clamping-holes. These things are indicative of the good results of cooperation between industry and the laboratory.

EARLE M. BUCKINGHAM[11]:—I was much interested in what was said in regard to hopper and magazine feeds. It may be of interest to know that in the majority of cases a hopper feed would seldom get as high in the rate of production as your magazine feed. The hopper is automatic, and imperfect pieces go through and it sometimes jams. In general, a hopper feed will give from about 80 to 90 per cent of the production that a magazine feed would give.

QUESTION:—How is increased production obtained by changing the cutting angles of the point of the drill?

MR. BOUTON:—Practically all drill manufacturers recommend a 59-deg. cutting-angle, which has been accepted generally as being the proper angle at which to grind the tool. However, many operations exist where changing this angle from 2 to 6 deg. either way will give higher production and longer life to the drill than if it were ground at the usual 59-deg. angle. Thinning the point of the drill is a very common practice among machine operators and, if an inspection were made of

[11] M.S.A.E.—Engineer, Pratt & Whitney Co., Hartford, Conn.

drilling operations in any plant, more drills would be found that are ground in some other manner than that of the standard called for by the manufacturers. These conditions will be found more in automatic screw-machine departments than in drilling-machine departments. The principal reason the operators have for grinding the drills in this manner is that it gives faster penetration, increased feed per revolution and, in automatic screw-machine operations, less thrust on the bar.

CHAIRMAN YOUNGER:— I would ask Mr. DeLeeuw whether, in the design of special drills or special tools, he knows of anything that is being done to take full advantage of the machinability of the new aluminum alloys that are being produced. I visited a factory the other day where they use considerable duralumin and tried to get information on speeds and feeds. They said that the metal would take all the machine could do, and that they had not reached the limit yet. Do you know of any instances where special machines are being designed for the newer light alloys which are gradually coming into use?

MR. DELEEUW:—This is merely one of the cases in which the machine has not caught up with the tool. In many aluminum alloys we can use feeds and speeds that the machine is not capable of furnishing. I agree entirely with Mr. Bouton that the twist-drill maker furnishes only one kind of twist-drill and recommends only one kind, whereas various kinds of work really require different thicknesses of points of different angles.

For instance, on automatic screw-machine work where deep holes may have to be drilled, it is very advisable to thin the point, not so much because it drills more easily as because the thin point prevents the chip from spreading out and hugging the walls of the hole; it lets the chip come out easier. That is very important on all automatic machinery. For wrought iron we should have an entirely different point than we have for harder material. For brass, again, we should have a different point, and when it comes to drilling such material as lead or copper or any soft material, we need to have a different point, different angles, from what we have for the ordinary drilling of cast iron or the ordinary range of steels that we use. That is a matter that really should be investigated and standardized. So far as I know, nothing has been done to publish data that can be applied in the shop and it is left to the individual operator or the foreman of a department to find the best condition for the particular job that he is doing.

DR. SCHLESINGER:—We are using an alloy, Silumin, which has 70 per cent aluminum and 30 per cent silicon; and another alloy, Elektron, composed of about 90 per cent magnesium, 8 per cent zinc, and the remainder lead and tin. This can be worked nicely at 800 ft. per min. cutting speed, but not with the ordinary machine. Ball and roller bearings must then be used extensively. The difference in practice caused by these developments is evident. I think that "light-metal" will be used to a greater extent in the coming year in automobile manufacture. It has about 1.8 specific weight, for Elektron, instead of 2.4 specific weight for Silumin and 2.9 specific weight for aluminum, and Elektron has about the same strength as brass and the same elongation, which means that it is stronger than cast iron.

THE MANUFACTURE OF PLATE GLASS FOR AUTOMOBILE USES

BY J. H. FOX[12]

ABSTRACT

GLASS was probably made first by the Egyptians and used in colored ornaments; that for glazing purposes was probably made at first by pouring the molten "metal" on to flat stones. Later, hand-blown cylinder-glass was made and this was followed by machine-blown cylinders and machine-made sheet-glass. All of these methods produce a fire-finished surface.

Polished plate-glass was made first in France. The principal process used in making it consists in melting the batch materials in pots placed in furnaces, pouring the molten "metal" on iron tables and rolling it into a rough-surfaced plate, then annealing the plate in an oven or lehr. The rough plate is then cemented to iron tables with plaster of paris, and the surface is ground to a plane with cast-iron shoes fed with sand. After smoothing with finer abrasives it is polished with felt pads fed with rouge.

A later process is a continuous one. The batch materials are melted in a tank furnace and the molten metal is drawn or rolled from the end of the furnace into a continuous ribbon, which then passes through an annealing lehr. The sheet is cut and laid on iron tables that pass in an unbroken line under the grinding and the polishing-machines. After reversing the plates on the tables, the other side is ground and polished.

The most objectional defect in automobile glass is a wavy surface, common in fire-finished glass, or unhomogeneous metal, known as "ream." Either of these defects causes distortion of view. Other serious imperfections are poor annealing, stones, large bubbles, heavy scratches and short polish.

THE DISCUSSION

C. W. AVERY[13]:—The experience of our company has largely been along the line of the continuous method of making glass. The continuous method requires more care in the melting department than does the pot method. The tank furnaces hold about 500 tons of molten "metal" each. If the materials going into those furnaces are not exceedingly uniform, contamination occurs, and a great amount of trouble follows which takes weeks to cure. It has been necessary at times to draw the 500 tons of metal out of the furnace to overcome the most serious trouble. The greatest troubles that come are due to variations of the materials. We have found that the sand used must be very high in silica content and not vary more than 1 or 2 per cent.

We have had opportunity to observe the two methods at close range, as we also have a plant of the pot-and-circular-table method. The first saving in the continuous method, compared with the pot method, is probably in the pots themselves, which are put in high-temperature furnaces to melt the glass. The pots themselves are expensive and do not last any great length of time. The maintenance cost of a tank furnace is only slightly greater than that of a pot furnace. The second saving is at the rolling machine. One man operates the rolling machine at all times, while, in the pot method, from four to six men are to be found working around the pots and rolling table.

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[13] Development engineer, Ford Motor Co., Detroit.

Mr. Fox brought out the point that there is not much extra cost in grinding the thicker glass down to the required thickness, and I agree with him. The rough grinding is the simplest part of grinding and polishing plate glass. The application of coarse grinding sand for a slightly longer period removes a considerable amount of glass. But I would say that the saving lies at another point, and that is in the furnace itself. If glass is rolled $\frac{1}{2}$ in. thick by one method and 5/16 in. thick by the other, only five-eighths of the amount of material goes into the furnace, which results in a saving of much heat as well as material. The next saving is made in the grinding department. When rectangular glass is put on a circular table, there must be some loss; and, when these circular tables are manipulated in rectangular buildings, there is a further loss. One is a loss of glass and the other is a loss of space.

Comparison of the original investments in the two types of plant is interesting. In the continuous method, the investment is about 50 per cent of that in the pot-and-circular-table method. Of course, this investment would be increased somewhat in a continuous method built to accommodate larger sheets. We are interested in automobile glass, and have attempted to roll glass only 40 in. wide and to grind and polish that same width. To build pot-and-circular-table plants of capacity equal to that of our continuous-method plants, twice the investment would be required. To illustrate, suppose that a plate-glass plant of the pot-and-circular-table method costs $10,000,000, and will produce 10,000,000 sq. ft. of plate glass in 1 year. On that basis, the investment in the continuous method producing 10,000,000 sq. ft. yearly will be $5,000,000. By actual comparison between two plants operating under exactly the same cost system and using the same materials, we have been able to reduce the cost of glass about 30 per cent by the continuous process.

At the present price of plate glass, no plate-glass company is making an extreme profit. The days of 20-cent glass for automobiles passed when automobile sizes ceased to be a by-product and became the main product. Twenty-cent glass was sold in the days when a very few cars were driven on the streets and only a small percentage of those cars had windshields. The plate-glass companies had more small sizes than they could sell and the automobile trade provided an outlet for that by-product. Now, the automobile trade uses more plate glass than any other trade, due largely to the increased use of enclosed bodies.

In the pot method, the thickness of glass is dependent largely upon the necessity of pushing the large sheet into the furnace. We have tried repeatedly to roll glass at Glassmere the same thickness that we roll it in Detroit, with little success. When that large sheet is pushed into the furnace, it must have a certain amount of resistance to prevent buckling and that, so far, has proved the only obstacle in rolling the sheet on the large table to the same thickness that we roll by the continuous method. The sheet rolled continuously is 5/16 in. thick. Recently, we have reduced the thickness 0.02 in. and expect to reduce it 0.02 in. more within the next few weeks. How much we can reduce the thickness depends upon the accuracy with which the sheet can be rolled.

QUESTION:—Of what material is the roller made that is used to roll molten "metal?"

J. H. FOX:—Cast iron, which has been found to be better than steel or any other material.

QUESTION:—What is the purpose of using arsenic?

MR. FOX:—Arsenic is not essential as a glass ingredient, but it helps to decolorize and to refine the metal. The various batch-materials are arranged so that bubbles of gas are given off at different temperatures and, at certain temperatures, it is desirable to have it given off freely so as to collect the fine seeds that pass very sluggishly up through the molten metal. Sodium is introduced in different forms, part in salt cake and part in soda ash, to bring about different chemical reactions during different parts of the process.

QUESTION:—You have objected to tensile and to compressive-strength tests. What methods of testing do you recommend?

MR. FOX:—Perhaps one of the most practical tests is that of using a glass cutter. The glass might have a very high strength on the surface that would test well in the testing machine as a beam, but would be brittle and difficult to cut, and would be undesirable as automobile glass. If the surface skin is very hard, it might show up very well in tests and not be desirable glass for automobile purposes.

QUESTION:—What is the percentage of breakage in grinding and polishing glass, for the circular-table and for the continuous system?

MR. FOX:—Breakage has a very wide range; 8 to 10 per cent is good performance. Bad temper of the glass is first noticed, usually, when the breakage in grinding and polishing is excessive. This is one way in which the glass is really tested for temper before it reaches the cutting room.

QUESTION:—What methods exist whereby bubbles and seeds and troubles of that nature can be eliminated?

MR. FOX:—To produce glass free from bubbles, boil and seed is the nightmare of plate-glass manufacturers and one of the most difficult problems to be met. As stated in answer to one of the previous questions, the object in using certain batch materials, such as arsenic and charcoal, and in using certain compounds of the essential materials is to bring about reactions at certain points in the melting and refining in which gases are given off freely, thereby collecting and carrying to the surface the seed and smaller bubbles which are more or less helpless alone. The reason for bringing the temperature of the glass up to approximately 2650 deg. fahr. and holding it there for a certain period of time is to make it possible to bring the bubbles and seed to the surface more easily, the glass at this temperature being very fluid and offering less resistance to the upward movement of the bubbles and seed than at lower temperatures. In addition to the use of batch materials that give off gases at certain temperatures to help in the refining, other devices are sometimes employed. One old method, known as "blocking," consists in pushing blocks of wood into the molten metal. These blocks in this intense heat freely give off gases due to their moisture-content and to their combustible material. Potatoes are sometimes used for the same purpose. In modern plants, however, dependence is placed entirely on the use of proper batch materials and temperature regulation of the furnace to bring about these results.

QUESTION:—What is devitrified glass?

MR. FOX:—Devitrified glass is glass that is partly crystalized and therefore more or less opaque. When cooled down from the molten state, glass passes through a certain critical temperature at which it will devitrify if cooled too slowly. For the usual plate-glass batch, this temperature is between 1800 and 1900 deg. fahr., although slight changes in the glass batch will change this temperature. It is important, therefore, that there

be no slow cooling through this temperature. This is not difficult to avoid so long as there is movement of the glass; but, in certain processes, there is danger of stagnant glass gathering at certain points having little or no movement and, if this happens to occur at the critical temperature, the glass is devitrified; then, with a change in the current of moving metal, it is carried out into the working stream of glass. This trouble is much more likely to develop in tank furnaces than in pot furnaces.

QUESTION:—How does aging affect strains?

MR. FOX:—No appreciable change due to aging should occur unless a batch is used that causes decomposition of the glass. I believe that tests have shown that glasses of certain compositions do show a reduction in strains after a period of time, due probably to flow of the material; but this change is not sufficient to make any marked difference on commercial glass.

QUESTION:—What is the minimum thickness that sheet glass can be made, in sizes up to 24 in. square?

MR. FOX:—This depends upon the process. In general, the cylinder processes are better adapted to drawing thin glass that the sheet processes. With the cylinder processes the thickness is limited, not by what can be actually drawn but by the difficulty of handling the cylinders and flattening without breaking. A thickness of 1/12 in. is as thin as is ordinarily commercially drawn of the 24-in. dimensions, although, by using great care, 1/16 in. or thinner glass can be made.

QUESTION:—Are optical means such as the use of polarized light ever employed for detecting strains due to improper annealing?

MR. FOX:—Optical means are used particularly for testing small objects such as optical glass and tumblers. I know of no practical way of using such means for testing plate glass, that is, testing the entire product of a plant, because, by this method, only small areas can be tested at a time.

QUESTION:—How does the rolling affect the internal stresses remaining in the sheet?

MR. FOX:—If the glass is allowed to soak long enough in the ovens of the lehr, it should recover completely from the effects of the rolling.

QUESTION:—How much internal stress is permissible? How can it be determined?

MR. FOX:—I presume the question refers to the difference between say the tensile stresses in the center and the compressive stresses on the surface. It is a difficult thing to measure; it can be determined better by the cutting. For automobile glass, I think the difference should not be very great, because toughness is what is wanted and, if the difference between the center and the surface of the glass is increased too much, the danger of chipping the edges is increased. For some special purposes, this tempering is carried to an extreme. For instance, I believe a German portlight is made in which the glass is tempered after it has been ground and polished, and very great compressive stresses are put in the surface; this process makes the glass very strong and apparently it can withstand fairly rough usage; but, when it breaks, it flies into many pieces and would be very undesirable glass for automobile purposes.

QUESTION:—Can the car builder buy the exact size of glass he requires; if not, why must he waste labor and glass in cutting to size?

MR. FOX:—I think that no trouble would be experienced in buying the size that is needed.

QUESTION:—What type of table is used in the continuous process; that is, how is the plate rolled at the Ford plant?

MR. AVERY:—The original table was one made up of platens about 6 in. wide and half the width of the table, fastened together on chains and running on true surfaces. The table was built in this way to overcome the warpage in the plates. The plates were kept small so that any possible warpage in each plate would not affect the whole to any great extent. We have since developed a drum type of machine in which the glass is passed between two rolls and onto a flat slab before entering the furnace, and while still plastic. This roll has made the thinner glass possible. In the original machine the platens would stick occasionally. Sometimes they would be a little high, and this would leave impressions in the glass; so, the glass had to be rolled thicker to take care of those defects. The drum type of machine is the latest development.

QUESTION:—Are there any advantages in the use of emery over those gained by using garnet or artificial abrasives?

MR. FOX:—That is largely a matter of cost. The supply of some artificial abrasives is very limited; but, for facing and producing a smooth surface on the glass, a variety of abrasives can be used. The whole thing is a matter of total cost per square foot.

QUESTION:—Is there a possibility for any great reduction in glass prices with present non-continuous methods?

MR. FOX:—Refinements are being introduced that make some slight change. I have no doubt that further improvements can be made.

QUESTION:—What is being done toward lessening the glare of reflected lights, such as street lights and store lights, in night driving of closed cars?

MR. FOX:—That is difficult to overcome. A glass with a good finish is bound to show reflection, and I do not see how it could be overcome in the glass itself.

QUESTION:—What glass defects should a car builder accept, and how can they be described?

MR. FOX:—That is a broad question. Automobile companies probably can answer it best. I have tried to outline in the paper in a general way what defects should be rejected and, to a limited extent, about how far they should go in other lines, but it is one of the problems in the judging of glass. Many attempts have been made to draw-up specifications outlining the defects that should be allowed in glass, such as limiting the bubbles to certain sizes and cutting-out certain defects but, although these may have some value as a general guide, the difficulty lies in that, even with specifications that limit the size of the bubbles, seed and other defects that may occur in certain sized plates, the glass will be of poor quality if the maximum of each one of all those defects is allowed in a single plate. A sheet or plate of glass that is comparatively free from most of the defects, but has say one or two of the defects to a somewhat greater degree than the specification permits, may be debarred and yet be very much better glass than another plate that meets the specifications but has a variety of all defects that are just inside the limits. For that reason the determination of the quality of plate glass still depends largely upon the judgment of the inspector, and he must pass upon the quality after basing his opinion on the total amount of information before him. It is very difficult to specify more than the major defects. Certain major defects, such as stones, should be cut out; but, for minor defects such as seeds, it is very difficult to draw up specifications that really mean much.

CHAIRMAN G. L. MCCAIN[14]:—Probably the matter is very largely one of the relation between the inspector and the glass manufacturer. If the inspector understands the manufacture of glass and what quality he can reasonably expect, the difficulty probably would be much less than if the inspector took the arbitrary stand that he must have glass of a certain thickness and that it must be perfect. One great trouble in the use of glass is its variation in thickness. For instance, the windshield is made to take a certain thickness of glass and the glass varies in thickness considerably.

MR. FOX:—Certain limits should be put on the variance in thickness; but, to work too closely to dimensions would add greatly to the cost of the glass. The better the rolling equipment is working, the more uniform the rough plate and the finished product is, but, even when those are all up to a high standard, some variation will still be found unless the glass is faced to a certain dimension and measurements are made. It is a question whether it is not less expensive to accept certain leeway in that regard and then to make the adjustments in the mounting of the glass rather than to adhere too strictly to dimensions that add to the cost.

CHAIRMAN MCCAIN:—Another great difficulty that the car builder has occurs when the glass that is rolled this month varies from the glass that is rolled say 6 months thereafter and yet is used in the same body or in the same windshield. That represents the tolerance to the men who receive the glass as much as does the tolerance in the rolling of the glass in a given batch over a given period. What is the percentage of loss in the interval between the casting process and the finishing process?

MR. FOX:—It varies. For instance, a certain percentage of breakage occurs in the lehr which will vary somewhat, depending upon the life of the lehr, and the percentage may be affected to a certain extent by weather conditions. The range in the total loss is wide. It may run up from 12 to 15 or 20 per cent or even higher.

CHAIRMAN MCCAIN:—Does the continuous process make the amount of loss between processes considerably less?

MR. AVERY:—We find that the loss in the continuous process is considerably less because of the use of rectangular tables. It is necessary of course to fill out the round table with glass that has to be cut to a circular shape on the outside. I would say that the comparison is about an average loss on circular-table methods of 20 per cent, and an average loss on the continuous method of from 8 to 9 per cent.

CHAIRMAN MCCAIN:—That will help toward increasing the amount of production obtainable and decreasing the cost of the glass.

MR. AVERY:—That is one of the savings.

CHAIRMAN MCCAIN:—What variation in thickness is commonly allowed by the glass maker in glass rated at ¼ in. in thickness?

MR. FOX:—There is really no general standard for that, although the Government has a certain standard for glazing glass.

CHAIRMAN MCCAIN:—A reasonable tolerance is desired, one that is perfectly commercial in every way. For some purposes of course it would be necessary to limit it much closer than 1/32 in.

J. L. MAYER:—In reference to the continuous process, how is glass made into sections so that it can be ground?

MR. AVERY:—A continuous ribbon passes through the annealing furnace and is cut at the cold end in strips just long enough to meet the requirements for the car. We usually cut three windshield-lengths. The tables are bolted solidly together, which makes it possible to lay the glass over the joints of the tables, so it makes no difference what length we cut it. We cut to the best advantage and find that three windshield-lengths handles best.

MR. MAYER:—Is there any tendency of the glass to buckle in the annealing furnace before it is cut?

MR. AVERY:—No. It will buckle before it gets its permanent set, but that is before it enters the lehr.

CHAIRMAN MCCAIN:—Is the use of reinforced glass feasible? For reinforced glass, two layers of glass are used, one on either side of a layer of celluloid. This glass was used during the war and was to prevent its shattering when bullets passed through it.

MR. FOX:—I believe that is a French patent, and that the chief trouble is the discoloration of the layer of celluloid between the two layers of plate glass. It reduces the shattering of the glass but it discolors with age and is expensive, particularly when two pieces of polished plate glass are used. If sheet glass is used, it causes a distortion of view.

T. J. LITLE, JR.[15]:—Reinforced glass is used in the police flivvers here. Although it has a yellowish cast, no particular objection has been made to it because it is a necessity in a case like that. It is used very generally for that purpose. It is about 1 in. thick, made up in three layers.

[14] M.S.A.E.—Automotive engineer, Link Belt Co., Detroit.
[15] M.S.A.E.—Chief engineer, Lincoln division of the Ford Motor Co., Detroit.

HIGHWAY EXPENDITURES AND MAINTENANCE

IT is generally agreed that the peak of highway expenditures in this Country has been reached but that it will remain fairly constant at around $1,000,000,000 a year for the next 10, 12 or 15 years. By that time the Federal highway system, as now planned, will have been improved and will include all highways for general motor-vehicle use. In addition to the Federal highway system, a number of trunk lines will carry very heavy traffic between large cities in congested districts. These new lines will also be used to bypass through-traffic around the congested parts of our cities.

State Engineer Upham of North Carolina has said that it can be easily shown from the returns on the gasoline tax that the average amount of gasoline used per car has been considerably less since various state highways have been maintained, and that this saving in gasoline alone more than pays for the maintenance of the entire system. In addition, other savings of tires, upkeep on vehicles and, greater than anything else, the saving of time in transportation are effected. If this is true, and it is true, the user should pay, and he will pay gladly, if he can be convinced that he will get his money's worth.

In States where the income from motor vehicles is sufficient to meet all maintenance costs of highways for general motor-vehicle use without undue burden to the individual motorist, any surplus should be used for the construction of such highways. In States where the number of motor vehicles will bring in large sums in excess of the highway maintenance cost without placing undue burdens upon the individual motorist, such surplus should be used to defray all the costs of maintenance and a substantial share of all of the other costs of highways for general motor-vehicle use.—A. J. Brosseau.

Instruments for Automotive Research

By John A. C. Warner[1]

Annual Meeting Paper

ABSTRACT

DUE to tremendous production schedules and rapid advancement, the automotive industry is characterized by its effort to learn the answers to engineering research-problems with utmost dispatch, but the procedure is not without attendant risks. Costly errors have resulted from experimental work improperly planned and executed, from conclusions too quickly drawn and from unjustified interpretation of observed indications. Cut-and-try procedure is resorted to in many instances after hastily applied research methods have failed and, often, the apparently longer course involving systematic research would, in fact, have been fruitful of more prompt and more satisfactory results at a lower net cost.

As originally presented, the paper was accompanied by a demonstration of instruments and apparatus especially adapted to automotive-research problems. These exhibits included

- Bureau of Standards
  - Apparatus for measuring fuel flow by volume
  - Carbon pile telemeter
  - Clearance volume indicator
  - Decelerometer made by the American Instrument Co.
  - Engine indicator made by the American Instrument Co.
  - Pedal pressure indicator
  - Vibrometer
- The Cambridge & Paul Instrument Co. of America, Inc.
  - Electrical apparatus for exhaust gas analysis
- Engineering Division of the Air Service
  - Elverson oscilloscope
  - Farnboro electric engine indicator
- International Motor Co.
  - Riding-qualities accelerometer
- Lubricating Appliance Mfg. Co.
  - Apparatus for determining viscosity and dilution
- Rotostat Instrument Co.
  - Stroboscopic apparatus
- University of Michigan
  - Apparatus for measuring fuel flow by weight
  - Gas analysis apparatus
  - Loudness evaluator developed for the Timken Roller Bearing Co.
  - Modified engine indicator
- Waukesha Motor Co.
  - Phoneloscope for the study of sound, made by H. G. Dorsey

Regarding instrument design and construction, reference is made to the comprehensive but concise rules of Clerk Maxwell, the well-known English scientist, and he is quoted as saying that the fundamental principle is that the instrument should be adapted to the use that is to be made of it and, in particular, that the parts intended to be fixed should not be liable to become displaced; that those which ought to be movable should not stick fast; that parts which have to be observed should not be covered up or kept in the dark; and that pieces intended to have a definite form should not be disfigured by warping, straining, or wearing.

After discussing the subjects of instrumental accuracy, simultaneous indications or records and types of instrument and of apparatus adapted to use in industrial laboratories, the author considers cost factors. Brief descriptions of motion analysis, motion-picture and stroboscopic methods and the study of noise are presented also, and types of devices used in these studies are specified.

ENGINEERING progress depends very largely upon fundamental and practical research. Research, in turn, involves experimentation, and experimentation presupposes the use of instruments and apparatus suitably applied by appropriate methods. Considerations that apply in general to instruments adapted to automotive research are discussed in this paper.

Industrial Conditions

The automotive industry, perhaps more than any other, is characterized by its effort to obtain with utmost dispatch the answer to engineering research problems. Tremendous production schedules and rapid advancement demand this, in itself an entirely commendable objective. The required procedure is not, however, without its hazards; and costly errors have resulted from experimental work improperly planned and executed, from conclusions too quickly drawn and from unjustified interpretation of observed indications.

Cut-and-try procedure is resorted to in many cases after hastily applied research methods have failed. Ofttimes the apparently longer course involving systematic research would, in fact, have been fruitful of more prompt and more satisfactory results at a lower net cost.

Design and Operation

For a masterful statement of the fundamental principles of instrument design and construction, it is difficult to improve upon the comprehensive but concise rules laid down many years ago by the well-known British scientist, Clerk Maxwell. In his General Principles for the Construction of Apparatus, he wrote in part:

> Certain primary requisites exist which are common to all instruments and which, therefore, are to be carefully considered in designing or selecting them. The fundamental principle is that the construction of the instrument should be adapted to the use that is to be made of it and, in particular, that the parts intended to be fixed should not be liable to become displaced; that those which ought to be movable should not stick fast; that parts which have to be observed should not be covered up or kept in the dark; and that pieces intended to have a definite form should not be disfigured by warping, straining, or wearing

The requirements of good design may well be classified under the headings of adequate accuracy and sensitivity, sturdiness and durability, adaptability or convenience in use, good workmanship and reasonable cost. When these items are considered separately and briefly, it can be said, with regard to the degree of accuracy and sensi-

[1] M.S.A.E.—Research manager, Society of Automotive Engineers, Inc., New York City.

tivity, that these features should be determined with respect to what is expected of the indications or records. An extremely sensitive instrument will show relatively large indications for small differences in the values to be measured. This feature may easily be carried to the point of absurdity if the design is accomplished without due regard for the requirements. Accuracy should be known and constant within reasonable limits. The sources and magnitude of errors should be known and the errors should be constant, so that appropriate correction factors can be applied.

Instrumental accuracy involves a number of important and interrelated factors, among them being time-lag, lost-motion and elastic hysteresis. From the point of view of the automotive engineer, the question of time-lag is perhaps one of the most vital. Automotive research often involves the study of motion of moving parts; for example, it is often required that an observation be made at a definite point in a given cycle or series of conditions. The natural ability or frequency of response of the instrument must be sufficiently rapid to indicate or record the phenomenon in question before it is too late. At the same time, the parts must be chosen and arranged so that resonant effects do not enter to invalidate the indications. The inertia of moving parts, lost-motion, suitable damping and other features are extremely important in this connection.

It is often desirable to obtain indications or records of several events that take place simultaneously. In this case it is essential that the various instrument elements be designed and arranged so as to make possible the perfect synchronization that is required; otherwise, the apparent relationship will be meaningless.

Instruments and apparatus adapted to use in industrial laboratories should be sufficiently sturdy to eliminate the possibility of damage through mishandling. This requirement also applies to the contingencies of transportation. It is advisable to have all vital parts enclosed or shielded wherever possible and, where fragile pivots or the like parts are involved, provision often can be made by the use of stops, locks or safety devices to render the moving parts inactive when not in use.

Lightness and small over-all size consistent with other requirements are to be recommended, especially when observations must be made consecutively from different points with some degree of dispatch. Parts that require adjustment or manipulation should be fashioned and located so as to be accessible and convenient to operate. Scales should be marked clearly and placed so as to make observations possible without fatigue.

Cost Factors

Many of the most serviceable and valuable instruments and laboratory set-ups are constructed from miscellaneous material, using a screw-driver and a pair of pliers with a generous admixture of ingenuity. It is often undesirable to expend relatively large sums of money on instruments that are to be used for a short series of observations only, and that can be constructed in homely fashion with the minimum expenditure of time and funds. Flawless finish is impressive but is often unjustified.

One cost factor that should be given special consideration is that involving recording versus indicating instruments. Many investigators show a tendency to render entirely automatic the instrumental functions in *all* research problems. This is often a mistake, for, aside from the difficulties associated with the design and construction for recording, there is also the expense item which should be very carefully analyzed. For example, certain experimental instruments are intended for a very brief period of use only. A laboratory assistant could be hired at small cost to make the necessary observations from an indicating instrument. In view of this fact, it would be absurd, all other factors being equal, to expend a sum for rendering the instrument continuously recording that would be much greater than the probable expense involved in hiring the assistant.

It is not within the scope of this paper to consider the features of all classes of instrument adapted to research in the automotive field; a brief discussion will, however, be devoted to devices for the analysis of motion and sound, two types of phenomenon of prime importance to the automotive engineer.

Motion Analysis

Within certain limits, the human eye can be used as a tool for investigating the action of moving parts. Owing to persistence of vision, however, the rapid motions that appear blurred to the unaided eye must be studied by other means. Two of the most interesting methods involve the use of motion-picture photography and the stroboscope.

Motion-Picture Methods

In his article on the Analysis of Complex Rapid Mechanical Motions[2], A. W. Judge has reported interesting data concerning photographic and stroboscopic methods of motion analysis. He describes very interestingly a motion-picture camera that is capable of making photographs at a speed of 5000 per sec. Incidentally, this camera cannot be called "portable," inasmuch as it weighs approximately 4 tons. The Bull method of photography, employing an electric spark to make and to regulate successive exposures, is widely known and requires no explanation here. The Jenkins method is also of interest. It is described in an article entitled the High-Speed Camera[3], by S. Francis Jenkins.

The obvious advantages of motion-picture methods over a range extending from the normal rate of 16 exposures per sec. to the higher speeds already referred to include the possibility of either a step-by-step or a slow-speed analysis of actual and relative motions of automotive parts from projections that magnify the interesting dimensions as desired. Quantitative records can be obtained by the use of appropriate scales. Time indications can be recorded by including a chronometer in the field or by the use of a tuning-fork or similar arrangements that mark definite time-intervals on the film.

Photographing speeds of from approximately 175 to 350 exposures per sec. are of interest to automotive engineers who desire to study the engine. The cost of the negative and the positive films alone for a 16-per-sec. positive record 1 min. long is estimated to be approximately $10. The cost of the negative film for a 200-per-sec. record 1 min. long is about $62, and for a 5000-per-sec. record 1 min. long the cost is about $1,500.

Stroboscopic Methods

The persistence-of-vision phenomenon is again utilized to advantage in stroboscopic methods of motion analysis. The more commonly used stroboscopes provide a motor-operated rotating disc or shutter which successively masks and exposes to the vision the part in motion. By properly regulating the speed of rotation of the shutter with respect to the speed of the part to be observed, the operator can in effect "stop" or "reduce" the motion of

[2] See *Automobile Engineer*, September, 1924, p. 265.
[3] See *Tech Engineering News*, March, 1924, p. 361.

the part and thus facilitate the study of its action. The shutter can be synchronized with the engine by connecting it either directly or through a flexible connection to the camshaft or the auxiliary shaft. This practice is followed in the familiar Elverson oscilloscope[4], a stroboscopic device that provides a "creeper-gear" for "stopping" or "reducing" the speed of motion as desired.

In this device, the conventional shutter is replaced by an ingenious arrangement for illuminating the part under investigation at intervals determined by the degree of speed reduction required. The part is observed under illumination provided by neon-filled lamps that are brought into action intermittently by a contact breaker connected to the engine. If the breaker is set to break contact at the same point in successive cycles, the part will appear stationary. Otherwise, the setting may be such as to "reduce" the motion suitably.

The Study of Noise

Direct analysis of sounds or noises by the human ear possesses the limitations characteristic of other human records. Such determinations are at best uncertain and approximate. Various devices and methods can profitably be applied in automotive work to the detection of noises and to the location of their sources. The analysis of these noises can be used to advantage in effecting suitable remedies.

Among the devices first introduced for locating noises or vibrations of a mechanism was the familiar listening rod, one end of which could be rested upon the machine while the other end was held to the ear or between the teeth. The next step brought apparatus employing a diaphragm and resembling a doctor's stethoscope. Today, a number of instruments of this type[5] are available. They are, in certain instances, arranged to allow the noise under investigation to be compared with a sound of known characteristics originating from a standard source.

More recent developments resort to electrical means, including electron tubes for the study of sound. Perhaps the first instrument of this type to be presented publicly is that demonstrated by F. A. Firestone in Detroit at the 1925 Annual Meeting of the Society of Automotive Engineers[6]. This instrument was designed to give quantitative indications of loudness or intensity of sound, independent of pitch. It consists essentially of a receiver connected in an electric circuit that includes a number of electron tubes; suitable capacities, resistances and inductances; and a sensitive alternating-current voltmeter from which loudness indications are observed. Means are provided for sensitivity adjustment. This instrument can be applied to the measurement of sound as it is transmitted by air impulses or, by the use of a suitable receiving element, it can be employed to study the vibrations of solid bodies; for example, bearings. Later developments in this type of apparatus may be expected to include filters by which certain ranges of frequencies can be selected and studied separately.

Apparatus designed to *record* noises ordinarily employs some form of sensitive diaphragm that responds best to a range of frequencies corresponding to the phenomena under investigation. The movements of this diaphragm are magnified by an optical lever-system which throws a light-beam upon a sensitized photographic-record chart. The Low-Hilger audiometer[7] is an instrument of this type.

Conclusion

It is the object of this paper to (*a*) present with special reference to automotive-research requirements the more important fundamental factors involved in instrument design; (*b*) review and explain briefly methods and devices for the study of moving parts and for the investigation of noise, two subjects of especial interest to the automotive fraternity, and (*c*) make available reference material that may be useful to research engineers who are interested in the topics discussed.

[4] See *Engineering Production*, Nov. 16, 1922, p. 462; also *Engineering*, (London), Dec. 8, 1922, p. 720.

[5] See *Automobile Engineer*, April, 1923, p. 109.

[6] See The Journal, February, 1925, p. 121.

[7] See *Engineering*, (London), Jan. 25, 1924, p. 108.

AUTOMOBILE ACCIDENTS

The ratio of injuries inflicted to the number of automobiles registered is steadily decreasing. That is convincingly indicated by the data contained in Table 1 which are taken from the *Bulletin of Safety Education*, dated Feb. 1, 1925, published for the education section of the National Safety Council, by the National Bureau of Casualty and Surety Underwriters, relative to automobile-accident death-rate per 10,000 cars. But by thorough measures for prevention the absolute number of automobile accident injuries can be largely reduced.

TABLE 1—AUTOMOBILE-ACCIDENT DEATH-RATES FROM 1915 TO 1923 INCLUSIVE PER 10,000 CARS

Year	Rates
1915	24.0
1916	20.8
1917	18.2
1918	15.5
1919	13.0
1920	12.0
1921	11.9
1922	11.6
1923	10.3

In Connecticut, according to Bulletin No. 13 of the Department of Motor Vehicles, dated Nov. 18, 1924. the State Police were put on the roads in full force on May 1, 1924. The comparative figures of fatal accidents presented in Table 2 show the results.

TABLE 2—FATAL AUTOMOBILE ACCIDENTS IN CONNECTICUT

	1923	1924
January to April	37	88
May to October	185	140

BOUNDARY LUBRICATION

WHILE Osborne Reynolds succeeded in devising a mechanical explanation of the friction of fully lubricated surfaces, it has been argued by some that his hydrodynamic theory has no bearing on ordinary journal lubrication where the oil-film is incomplete, and that to explain this it is necessary to introduce a new concept. This is known as "boundary lubrication," the idea being that with a good lubricant a layer of molecules "welds" itself to the opposing surfaces, making these surfaces those of solid lubricants, whatever this term may imply. Osborne Reynolds, on the other hand, maintained that the hydrodynamic theory applied equally to imperfectly lubricated, as to fully lubricated, bearings, and held that the differences in behavior were due to the circumstance that with such bearings the load was concentrated on the "high points" of the opposing surfaces. Round these the lubricant must be collected by surface tension and, should any movement of the opposing surfaces occur, there must undoubtedly be hydrodynamic lubrication in these regions. It does not seem possible to avoid this conclusion, and as a first result we get accordingly the certainty that in the various experiments which have been brought forward to demonstrate "boundary lubrication" there must certainly have been some amount of "hydrodynamic" lubrication. It may further be added that Osborne Reynolds claimed that under the conditions of scanty lubrication the friction on his hydrodynamic theory would be proportional to the load and independent of the nominal area of contact, which is what experience shows to be the case.

On Osborne Reynolds' theory the problem of the resistance of greasy surfaces is a problem in fluid friction, while on the opposing view the matter is a question of solid friction.

Former students of solid friction were led to the conclusion that the friction of solids was due to the "asperities" of the opposing surfaces. W. B. Hardy argues that the experimental results prove that, if this be true, the asperities must be of molecular dimensions, and he asserts that if the resistance to motion were due to the inter-engagement of such asperities, it would be impossible to explain the fact that the total friction is independent of the area of the opposing surfaces, and proportional to the load. This rule, he states, holds even in the case of the friction between a clean watch-glass and a clean sheet of plate glass, although as he points out the nominal area of contact varies, in this case, as the two-thirds power of the pressure applied. This independence of the friction and of the area of contact is, he claims, sufficient to show the error of the older view. It would seem, however, that this conclusion does not necessarily follow from the premises. When the load on the watch-glass is increased, the alteration of the nominal area of contact is not the only phenomenon involved. The points previously in contact are not unaffected by the increase of pressure, and, further, it may be observed that in any case the true area of contact is very much less than the nominal, since it is impossible to make surfaces absolutely true to form so that they bear all over. In fact, the whole matter is exceedingly complicated, and, until the problem presented has been fully analyzed, the observation cited cannot suffice to overthrow the older view.

Mr. Hardy claims that solid friction arises from a certain cohesion between the molecules of the opposing surfaces, stating that

> To understand how two molecules may act, consider an interface between two masses of matter. A molecule on one side of the interface will be attracted by the matter on the other side, which is within the range of its force of attraction. A tangential force will therefore tend to move the molecule from its position of equilibrium.

He definitely speaks of the "cohesion" between the molecules of the opposing surfaces and compares the failure when slip occurs to the rupture of a more or less plastic solid.

A strong argument against the validity of the hypothesis thus put forward seems to lie in the fact that when slip ensues between clean, solid surfaces, scoring or other injury always occurs. Now it is hardly conceivable that the attraction of a molecule in the one surface to another in the opposing surface should be greater than its attraction to its immediate fellows below and around it. If the intimate character of the phenomenon were as Mr. Hardy describes it, slip ought, it would seem, to occur without any mechanical damage whatever, while if actual interlocking of the "asperities" occurs, this scoring is exactly what we should expect. On Mr. Hardy's theory the forces causing solid friction are tractions, the cohesion between the opposing molecules having to be overpowered. On the other view the forces concerned would be the thrusts and stresses involved, the same in character as those arising in the collision of the molecules of a gas and the "asperities" concerned would either have to yield, or the load be lifted in some way, before slip could occur.

Mr. Hardy further says that "at the free surface of a solid the condition of minimum of potential of the surface energy involves an orientation of the molecules of the surface layer such that their major attractions are in the plane of the surface." He brings this forward in explanation of the fact that when two very perfectly finished surfaces—such, for instance, as those of the Johanssen gages—are brought into contact they adhere firmly together unless they have been previously very thoroughly cleaned, in which case no adhesion is perceptible.

Beilby has shown, however, that the layers of a polished surface consist really of a super-cooled liquid, and according to Van der Waals the density of the surface layers of a liquid is less than the average of the mass, the molecules becoming farther and farther apart as the surface is approached, and consequently the attractive forces are less at the surface than farther in. If, on the other hand, Mr. Hardy is not considering this surface as a super-cooled liquid, but as a normal elastic solid, then it is not the case that resultant tractions are the maximum where the potential energy is the minimum. In any case, however, the resultant force on any molecule must be greatest normal to the surface, and not tangential to the surface, as Mr. Hardy's language would appear to indicate.

It does not seem, therefore, that these views of the nature of solid friction afford any very sure basis for the hypothesis of "boundary lubrication," according to which a layer of oil one molecule thick can serve as an effective lubricant. It is now admitted that a good lubricant welds itself to the surfaces it lubricates, and, were it possible to coat two surfaces each with a layer of oil one molecule thick, we would naturally expect that the force under which slip occurred would not be the same as with two clean surfaces. It would be an abuse of language, however, to call this lubrication. We have only to replace the layers of oil by, say, an electrolytically deposited layer of gold, also one molecule thick, and we should again expect that the force under which slip occurred would be changed by the deposit. If the result were a decrease, no one would think of saying that the gold acted as a lubricant, and from the physical standpoint the two cases are evidently identical.

Mr. Hardy and Miss Doubleday say,

> Most lubricated surfaces have the curious property that the friction falls after the lubricant has been applied until a steady state is reached after an interval which may vary from a few minutes to a few hours. The most striking fact is the influence of the slider. The final steady state is never reached unless the slider is in position. Surfaces which have been freely exposed to vapor or to an excess of fluid resting on them have always a high friction when first put into contact. The lowest friction is only given by a film of

lubricant which has been enclosed for some time between two solid surfaces.

The authors observe that the molecules of a good lubricant are like rods loaded at one end, and that they tend to orient themselves normally to the surface. This view is now very thoroughly established, but it is difficult to accept the view that the time lag observed in the authors' experiments represented the time required to effect this orientation. When a film of oil spreads over water, the orientation seems to be practically instantaneous. Moreover, the oil molecules at lubricated surfaces are being jolted up and down millions of times per second owing to the thermal agitation, and it is very difficult to believe that any orientation which cannot be completed within the myriads of oscillations corresponding to an interval of a few seconds would be effected by a longer lapse of time. Again, the fact that the phenomenon is only fully developed with the slider in place seems highly significant. In view of the "polar" characteristics of the molecules of the lubricant, it would be natural to expect that the approximation of the two surfaces would tend to disturb any existing orientation rather than to promote it, as will easily appear if we regard the oil molecules as small magnets each tending to fix, say, its north pole on the surface to which it adheres. These considerations indicate that an explanation of the observations must be sought elsewhere, and, if we assume that Mr. Hardy was not really dealing with monomolecular films, another explanation of the time lag becomes possible.

When oil spreads on water it tends to form a layer one molecule thick. Any excess over that required to cover thus the whole water surface collects itself into little lenses, the aim of the oil being to get as large an area as possible of mono-molecular thickness. Hence the lenses in question may be, and very commonly are, a relatively large number of molecules thick.

It is reasonable to assume that the same phenomenon will occur when oil spreads over a metal surface. The surplus fluid will again gather itself into these little lenses, and when two very scantily-oiled surfaces are pressed together these lenses will tend to collect round the regions of closest contact. For this, time is required, but once these aggregations are achieved the conditions for hydrodynamic lubrication are satisfied. On this view, therefore, the question of lubrication does not enter into the study of static friction. The adsorbed oil acts then merely in the same way as would an electrolytically deposited layer of some metal having a lower "clean" static friction than that of the surface on which it is deposited. In kinetic friction the lubrication is hydrodynamic, and the difference between a good and a bad lubricant lies in the fact that the bond between the metal is stronger in the first case than in the latter. Under the conditions of imperfect lubrication the shearing stress tending to tear the oil away from the surface becomes very great, and with a bad lubricant the adhesion breaks down and the two solid surfaces come into contact.—*Engineering* (London).

COLD-DRAWN TUBING

A VAST quantity of seamless tubing is made by the cold-drawn process. The first step in this is to point the end of the tube by swaging it down under a power hammer. The tubes are then cleaned and freed from mill-scale by pickling them in a hot acid bath. The cold-drawing apparatus consists of a very heavily built horizontal steel draw-bench, in the center of which is firmly positioned a hard die through which the tube is to be drawn down. In front of the die is located a heavy endless chain which runs over a wheel located underneath the dies and travels along the top of the draw bench and in a direction away from the die, for a distance of from 15 to 40 ft., and then passes over a sprocket which is power driven. The chain is endless and returns underneath the draw bench.

The hot-rolled tube, which is now perfectly cold, is inserted in the die with its pointed end projecting toward the endless chain. A mandrel is then slipped into the tube from the rear until it lies in the proper position within the die. Then an operator seizes the pointed projecting end of the tube by very massive tongs, which are hooked to the endless traveling chain above described, and by this means the tube is drawn or squeezed through the die; that is to say, between the die and the mandrel which has been previously inserted. All tubes except those of ½-in. inside diameter and less, and those tubes in which the wall is very heavy relatively to the diameter, are drawn over mandrels in this way. The dies, which, of course, are subjected to very heavy service, are made of the best grade of crucible steel and are machined down to the thousandth of an inch so as to govern accurately the outside diameter of the tube. These tubes are drawn from 2 to 20 times through dies of varying diameter and are thus brought down gradually to the required dimensions.

Cold-drawing makes the tube hard and brittle and, hence, after each draw-pass the tube has to be annealed to make it soft enough to withstand the next drawing. Annealing forms scale on the tube, and this is removed by pickling. That annealing is a very important step may be judged from the fact that it varies from a "light" annealing to remove initial stresses to a "long" annealing in a closed box to render the tubes very soft and ductile. Cold-drawn tubes are then passed through the straightening machine and from them to the cutting-off machine, where they are cut to the desired length. The Shelby seamless steel boiler tube is subjected to a hydrostatic pressure which varies from 1000 lb. per sq. in. for tubes under 5 in. in diameter, to 800 lb. per sq. in. for tubes in which the diameter is greater than 5 in. —*Scientific American.*

FORECASTING BUSINESS CONDITIONS

IT is well to understand that it is practically impossible to forecast, with any degree of accuracy, specific business conditions for any considerable period, even after allowances are made for the wonderful improvement in collecting and analyzing business facts and industrial statistics. Prosperity or depression is the result of a multiplicity of factors, many of which cannot be foretold because they are subject to factors entirely beyond man's control. The production of practically all food supplies and much of our clothing is dependent upon weather conditions, and science has not yet been able to foretell weather conditions, even a month in advance, not to mention the longer period covering the crop growing season. Good or bad business is a function or a result of many variables; and, consequently, until we are in a position to know something about the crop prospects for 1925, prognostication for a longer period must be subject to decided limitations.—W. P. Gephart, First National Bank in St. Louis.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 10, and March 10, 1925. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALLEN, EDWIN L., JR., (M) checker and designer, Cleveland Automobile Co., Cleveland, (mail) 1752 Noble Road, *East Cleveland, Ohio.*

BANKS, W. FOSTER (M) president, Motor Haulage Co., Inc., 18 Amity Street, *Brooklyn, N. Y.*

BLACKBURN, LEONARD ANDERSON (A) plant engineer, Olds Motor Works, *Lansing, Mich.*, (mail) 213 East St. Joseph Street.

BLAIR, F. R. (A) treasurer and general manager, Edward V. Hartford, Inc., West Side Avenue and Carbon Place, *Jersey City, N. J.*

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Applicants *for* Membership

The applications for membership received between Feb. 14 and March 14, 1925, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BACKHOUSE, KELVIN C., draftsman and assistant experimental engineer, Demattia Bros., *Garfield, N. J.*

BATSTONE, CHARLES E., road engineer, International Harvester Co. of America, *Boston.*

BAVETT, JOSEPH, mechanical superintendent, Yellow Cab Co., *Baltimore.*

BEACON OIL CO., *Boston.*

BOCKIUS, CHRIS, development manager, Manhattan Rubber Mfg. Co., *Passaic, N. J.*

COLTON, WILLIAM C., JR., tool designer, Wills Sainte Claire, Inc., *Marysville, Mich.*

DENISON, ERNEST B., salesman, Western Electric Co., *Detroit.*

DEVINE, ALFRED W., engineer, Registry of Motor Vehicles, *Boston.*

DOUGLAS, ALBERT L., service manager, Mack International Motor Truck Corporation, *Philadelphia.*

ELY, SUMNER BOYER, assistant professor of commercial engineering, Carnegie Institute of Technology, *Pittsburgh.*

FERRIN, ARTHUR W., engineer, Remington Oil Engine, Inc., *Keyport, N. J.*

GIBSON, ROBERT W., standards engineer, General Motors Corporation, *Detroit.*

HARMAN, CHARLES H., engineer and director of service, Stoughton Wagon Co., *Stoughton, Wis.*

HARTENSTEIN, HENRY R., automobile mechanic, Forest City Steamship Co., *Cleveland.*

HAYDEN, C. J., president, Hayden Automobile Co., *Stamford, Conn.*

HAZEN, LYSLE L., superintendent and designing engineer, Keystone Driller Co., *Joplin, Mo.*

HEPPENSTALL, CHARLES W., president and treasurer, Heppenstall Forge & Knife Co., *Pittsburgh.*

HERRICK, THOMAS F., rodman, Department of Highways for the Borough of Queens, City of New York, *Long Island City, N. Y.*

HYDE, ROLLIN M., sales engineer, National Radiator & Mfg. Corporation, *Detroit.*

JACKSON, ALLAN, director and vice-president, Standard Oil Co. of Indiana, *Chicago.*

JOHNSON, C. E., president, Piston Ring Co., *Muskegon, Mich.*

JUDKINS, JOHN B., president, J. B. Judkins Co., *Merrimac, Mass.*

KAPLAN, SAMUEL, executive, Monroe Furniture Co., Ltd., *Monroe, La.*

KNIGHT, WILLIAM, vice-president and general manager, Junkers Corporation of America, *New York City.*

LADISH DROP FORGE CO., *Cudahy, Wis.*

LARSON, CARL OSCAR, mechanical engineer, International Motor Co., *New Brunswick, N. J.*

LEE, R. K., assistant head of special problems section, General Motors Research Corporation, *Dayton, Ohio.*

LUQUE, ADOLPH, sales engineer, Gray Marine Motor Co., *Detroit.*

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MCDUFFEE, J. H., assistant to vice-president, Prest-O-Lite Co., *Indianapolis.*

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MARSDEN, W. S., assistant instructor in engineering mechanics, Sheffield Scientific School, *New Haven, Conn.*

MORVAN, CAMILLE P., draftsman, Edward G. Budd Mfg. Co., *Philadelphia.*

NOYER, LOUIS, civil engineer, Schlumberger & Co., *Paris, France.*

OHMART, GRAYSTON LEROY, engineer in equipment division, Department of Street Railways, *Detroit.*

PEASE, CLARKE D., president, Clarke D. Pease, Inc., *New York City.*

PERDEW, W. E., general manager of refining and marketing, Derby Oil Co., *Wichita, Kan.*

PIERSON, FRANK O., designer of jigs, Cruban Machine & Steel Corporation, *New York City.*

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SCIRA, JOSEPH A., shop foreman, Jerome J. Sloyan, *New York City.*

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SHARPE, FRANK A., district manager, Thermoid Rubber Co., *Trenton, N. J.*

SICKELS, GEORGE H., truck transportation manager, Mexican Petroleum Corporation, *New York City.*

SKELLY, JAMES H., tool designer, Lycoming Mfg. Co., *Williamsport, Pa.*

SLIGH, TOM S., JR., physicist, Bureau of Standards, *City of Washington.*

TORONTO HYDRO-ELECTRIC SYSTEM, *Toronto, Ont., Canada.*

WAGNER, WILLIAM PAUL, engineer, General Motors Corporation, *Detroit.*

WALWORTH, RICHARD H., mechanical engineer, Steel Products Co., *Detroit.*

WASSON, STOWELL C., sales agent, National Malleable & Steel Castings Co., *Indianapolis.*

WEIR, T. A., vice-president, Weir Co., *Omaha, Neb.*

WEITZEL, WALTER H., draftsman, Graham Bros., *Evansville, Ind.*

WICKS, W. A., president, Franklin-Wicks Co., *Seattle, Wash.*

ZECHER, ALBERT G., general foreman, California Highway Commission, *Bakersfield, Cal.*